JOURNAL

OF THE

Association of Engineering Societies.

BOSTON. CLEVELAND. MINNEAPOLIS. ST LOUIS.
MONTANA. ST. PAUL. DETROIT. PACIFIC COAST.
BUFFALO. LOUISIANA. CINCINNATI.

CONTENTS AND INDEX.

VOLUME XXIII.

July to December, 1899.

PUBLISHED BY

THE BOARD OF MANAGERS OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

JOHN C. TRAUTWINE, JR., *Secretary*, 257 S. FOURTH STREET, PHILADELPHIA.

[illegible]

CONTENTS.

VOL. XXIII, July-December, 1899.

For alphabetical index, see page v.

No. 1. JULY.

No. 5. NOVEMBER.

No. 6. DECEMBER.

INDEX.

VOL. XXIII, July-December, 1899.

The six numbers were dated as follows:

No. 1, July.	No. 3, September.	No. 5, November.
No. 2, August.	No. 4, October.	No. 6, December.

ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
Names of authors of papers, etc., are printed in *italics*.

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. JULY, 1899. No. I.

COVERED RESERVOIRS AND THEIR DESIGN.

BY FREEMAN C. COFFIN, MEMBER, BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 17, 1899.]

THE use of covered masonry reservoirs for the storage and distribution of underground water is becoming so general, wherever the elevation and local conditions admit, that a brief consideration of the reservoirs of this class which have been built, a study of the elements which enter into the design and an investigation of the cost of various sizes and depths of such reservoirs can hardly fail to be of interest.

Stand pipes, tanks or metal structures of any description, although used for the same purpose as earth or masonry reservoirs, are of a nature so essentially different that further reference to them is unnecessary in this paper. The covered reservoir is in the line of natural evolution from the open distributing reservoir, to meet the requirement of exclusion of light from underground or filtered water, although the necessity of providing a roof or covering of some kind leads to a different disposition of materials.

SOME EXISTING RESERVOIRS.

In referring to reservoirs that have been built no attempt will be made to treat the subject exhaustively, nor to go to ancient history for examples. A few prominent types will be very briefly described.

SOME ENGLISH RESERVOIRS.

In the Proceedings of the Institution of Civil Engineers, Vol. LXXIII, in the year 1883, Mr. William Morris describes a number

of covered reservoirs built in England. In the discussion that follows several others are described. Among them is nearly every type of roof covering that has since been built in this country. The arches of these roofs were all of the segmental barrel form. Their spans were from 7 to 17 feet in the clear, their rise from one-eighth to one-third of the span. In the earlier examples the arches were sprung from wrought iron girders, these in turn being supported by cast iron pillars. In later construction brick piers were substituted for the pillars, and later still brick lintel arches springing from brick piers supported the main arches. No groined arches were included among these examples of reservoir vaulting. Although concrete is employed extensively in the construction of the reservoirs, it is used in the covering arches in only two instances. Except for the spandrel filling, they are of brick in the others. In the cases where concrete was used the clear spans were 12 feet, and the rise 2½ feet in both. In one it was 9 inches thick at the crown and 18 at the skewback, in the other 10 and 20 inches respectively. But two of these reservoirs were circular in plan, the others being square or rectangular. In one of the circular ones the covering arches were concentric, and were supported on rings made of 12-inch iron I beams resting upon brick piers. The other round reservoir had a vaulting of unique design. It was 64 feet in diameter, constructed with nine radial arches springing from 12-inch I beams, which rest upon a large cast iron column in the center and upon the outer walls. The iron girders have a slope of 4 feet from the center to the wall. The arches have a span of 22 feet and a rise of 4 feet at the wall; the crown is level, while the span and rise diminish to nothing at the center. The thickness of nearly all of the arches was about 8 inches, or two rings of brick laid on edge.

The side walls were generally rather heavy. In one reservoir they were very light. These were of brick 14 inches thick, built in the form of vertical arches, with 10-foot span and a very slight rise. There was a brick buttress or pier at the springing of each arch. This form being designed to resist the pressure from the outside, it is evident that the inside pressure of the water was supported by the earth backing. These reservoirs are described in detail in the paper, and are illustrated by plates. English practice of that date is quite fully described in the paper and the discussion that follows.

In a paper published in the journal of the N. E. Water Works Association for September, 1888, Mr. Charles H. Swan describes some very interesting covered reservoirs in France. The following extract from his paper refers to one of the most striking features of the reservoir of Menilmontant: "The reservoir is covered by

groined arches composed of two courses of bricks laid flat in cement. They rest upon pillars 60 centimeters (2 feet) square and 6 meters (20 feet) between centers. . . . The brick arches are about 8 centimeters ($3\frac{1}{4}$ inches) in thickness, including the plastering. They were covered by a layer of earth and turf 40 centimeters (16 inches) thick."

AMERICAN RESERVOIRS.

There are at present a number of covered reservoirs in this country. The following is a brief description of several of these:

Newton Reservoir.

One of the earlier of these was built for the water works of the city of Newton, Mass., in 1890 and 1891. It was designed and built by Mr. Albert F. Noyes, city engineer. It is about 125 feet wide by 175 feet long and 15 feet deep. The walls are of rubble masonry, laid in Rosendale cement mortar, about $7\frac{1}{2}$ feet thick at the bottom and $2\frac{1}{2}$ feet on top on two sides and 5 feet on the other two. The covering is of brick arches 4 inches thick, with a clear span of 10 feet and about 10 inches rise. The arches are supported by rows of lintel arches of brick, which rest upon brick piers 20 inches square. The top of the arches is filled up level with concrete to a point 4 inches above the crown. Over this is a filling of earth about $2\frac{1}{2}$ feet thick.

Brookline Reservoir.

A covered reservoir was constructed for the water works of Brookline, Mass., in 1892. It is about 92 feet square and 19 feet deep; its construction is similar to that at Newton, except that the walls and piers are heavier. A description of it is given in a paper read by the engineer, Mr. F. F. Forbes, and published in the journal of the N. E. Water Works Association for March, 1894. These reservoirs are excellent examples of substantial construction.

Franklin Reservoir.

In the year 1891 Mr. F. L. Fuller, civil engineer, built a reservoir of admirable design and economical construction at Franklin, N. H. It is circular in plan, 70 feet in diameter and about 17 feet deep. The walls are of rubble masonry laid in Rosendale cement mortar, are 5 feet thick at the bottom and $2\frac{1}{2}$ feet at the top. The covering consists of two concentric brick arches and a central dome. The latter is 23 feet in diameter, with a rise of 3.25 feet. The arches have a clear span of 11 feet, and rise 1.50 feet; the thickness of the arches and dome is 8 inches. They are supported by two

rings of lintel arches and the side walls; the piers of the lintels are of brick, 1 foot square and 7 feet apart in the rings. The piers are much smaller for their load and length than it is customary to make them, and are certainly an interesting example of the extent to which ordinary practice can be departed from with success. Mr. Fuller has since built similar ones at Methuen and Winchendon, Mass. A description of this reservoir is given in the journal of the N. E. Water Works Association, 1892, page 82.

Waltham Supply Well.

In the journal of the N. E. Water Works Association for March, 1894, there is an interesting description of the covering of a supply well at Waltham, Mass., by Mr. Frank P. Johnson, civil engineer. There are arches similar to those at Newton and Brookline; these have a clear span of 11.5 feet, rise of 1.92 feet and are built of one 4-inch ring of brickwork with no concrete filling over them. There is also a circular dome 40 feet in diameter, 7 feet rise, built of what were called Guastavino tiles 1 inch thick; there were three thicknesses of these tiles in the domed covering. They foot at the skewback on a metal ring, which resists the outward thrust.

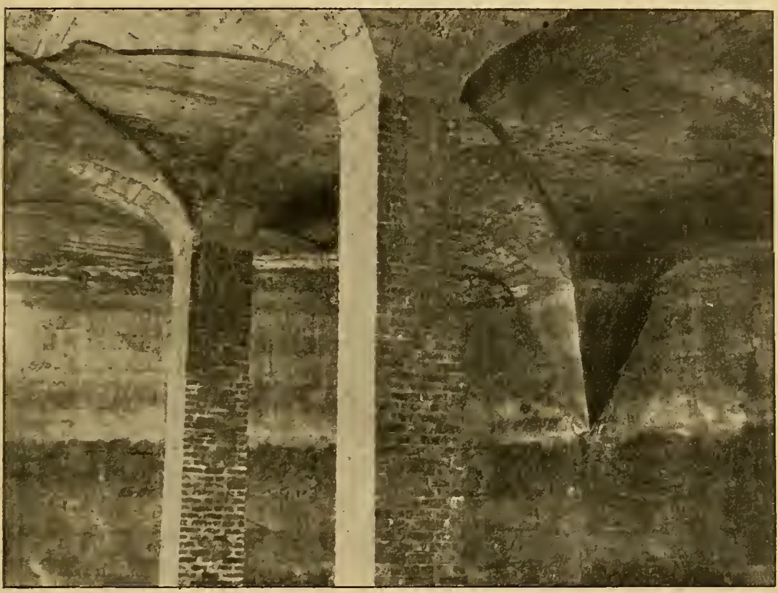
Wellesley Reservoir.

During the summer of 1898 the writer constructed some works for an additional supply of water for the town of Wellesley, Mass. The supply is an underground one, which was recommended by Mr. Desmond FitzGerald after a thorough investigation of all available sources. A covered reservoir of a capacity of 600,000 gallons was included in his recommendations. Mr. FitzGerald acted as consulting engineer in the design and construction of the works.

In designing the reservoir many types were considered, and it was finally decided to build it circular in plan, with a roof or covering of elliptic groined arches. It was first thought that such arches were not adapted to a circular reservoir, but further study showed that no real difficulties were involved. Designs for several depths were computed, and it was found that a depth of about 15 feet and diameter of about 80 feet was more economical for the required capacity than a greater depth. The dimensions of the arches and piers finally adopted fixed the inside diameter at 82 feet, and the depth from the floor to the springing line of the arches was made 15 feet. For a capacity of 600,000 gallons the water line is about 0.7 feet above the spring line, and the overflow was fixed at that point. Material for concrete was more available

than for rubble masonry, and the walls were designed of that; it was also decided to make the roof of concrete, as its cost is much less per yard than brickwork; and with the latter the thickness of the arches could not be made much less, besides this form of arch requires a great deal of cutting of the brick. The centering for concrete costs more, as it must be made tight and smooth; while that for brick can be made with a covering of narrow strips. Brick was chosen for the piers. The dimensions of the parts of the reservoir as designed were as follows:

Walls 15 feet high from floor to spring line, 2 feet thick for 5 feet below the spring line, 2.67 feet in the next lower 5 feet, 3.33



INTERIOR OF RESERVOIR SHOWING GROINED ARCHES.

feet in the lowest section. Piers 15 feet total height, 2 feet square, with a base 2.67 feet square at bottom. Foundations of piers 3.5 feet square, 1 foot deep. Roof arches 12 feet clear span, 2.5 feet rise, 0.5 feet thick at the crown, filled in level over the piers. The material of the excavation was a tight, clayey hardpan with very little water in it; the floor was therefore made only 4 inches thick. A steel ring of channel iron, weighing 32 pounds per foot, was set in the side walls just above the spring line. The earth filling over the concrete roof was designed as follows: Six inches of clean gravel next the concrete for drainage, and to prevent freezing to the concrete; this gravel went over the sides to the spring line, and was

drained by several lines of 4-inch vitrified pipe, which discharge at the toe of the embankment. Over the gravel 1 foot of earth from the excavation and then 6 inches of loam, making a total of 2 feet. The embankments were carried out at the level of the top to a point 7 feet outside of the inside line of the wall, and thence to the natural surface with a slope of 2 to 1.

The construction was executed as designed, with two exceptions. A great many bowlders were found in the excavation; the specifications provided that "the lower part of the wall might be made of these stones if the engineer should so direct, in which case it is probable that the thickness of the wall will be increased." This was done, and the wall made 4 feet at the bottom, or 8 inches thicker than designed, as shown in Fig. 1. It was thought that it would not be possible to make as strong work with these bowlders as with concrete. The smooth, rounded stones were split, the rubble laid against forms and so carefully bedded in the mortar that the writer is of the opinion that it would have been perfectly safe to have used the thickness designed. The other change was in the thickness of the earth covering. There being a surplus of loam, it was put on 1 foot thick, instead of 6 inches. This made the total thickness of the earth $2\frac{1}{2}$ feet at the walls and 3 feet at the center.

Portland cement was used throughout. That in the walls was the Brooks-Shoobridge brand; the vaulting was of Alsen, with the exception of about one hundred barrels of Atlas that was used because the Alsen could not be had in time. The concrete made of the Atlas seemed quite as good as the other. The number of parts of sand used to one part of cement were as follows: In rubble masonry $2\frac{1}{2}$, in the concrete in the walls 3, in the vaulting $2\frac{1}{2}$. The proportion of screened gravel used in the concrete was such that the voids were slightly overfilled. It required approximately 1.1 barrels of cement per cubic yard for the rubble masonry, 1.2 barrels for the concrete, with 3 parts of sand, and 1.3 for that with $2\frac{1}{2}$ parts. These figures are based upon the total amount of each kind of work and the number of barrels used in that work.

A ring made of channel iron, weighing 32 pounds per foot, was set in the side walls, with its bottom at the spring line of the roof arches. The bottom of the reservoir is covered with a floor of concrete 4 inches thick. This floor and the side walls are finished with two coats of plaster; one about $\frac{1}{2}$ inch thick, of mortar mixed in the proportion of 2 of sand and 1 of cement; this coat was leveled up, but not smoothed. The last coat was of neat cement, about $\frac{1}{8}$ of an inch thick, thoroughly rubbed in and smoothed with trowels. There were a few places where the walls were moist from the pres-

sure of the water on the outside, and some trouble was anticipated in making a good work with the plastering; but very little was realized, and it was in the best of condition when the reservoir was filled. The roof was not absolutely tight, and a very heavy rain coming on just as the plastering of a part of the floor was finished, there was some dropping of water in several places, which cut through the $\frac{1}{8}$-inch coat before it was hard and threw off a number of flakes. This made it necessary to plaster over a small portion of the floor. Twelve hours more of setting before the rain would have prevented this; the expense was, however, but a few dollars.

The centering for a roof of this type is an important and expensive factor in the work. Plans were made for centers that would each cover the space between four piers. The contractor believed that it would be better to reduce the size of the single centers, and, as he was not required to adopt the plans of the engineer if his own were satisfactory, he was allowed to use the smaller ones. The writer believes that the extra fitting caused by this change made the total cost of the centering much more than it would have been if the original plans had been followed. Whether this is so or not, the cost of the centers (if used but once), of the supporting timbers and the labor of erection and removal was about $22\frac{1}{2}$ cents per square foot for the inside area of the reservoir. The contractor's plan was to supply centers for one-quarter section of the reservoir only, and put the roof on in such sections. This was assented to by the engineer, with the provision that the heads of the piers should be thoroughly braced in each direction to the outside walls, and that if it was found necessary to have more centers in order to prevent delay they should be provided. Although a large saving in cost of centers would be made in this way, it is a mistaken policy, as it afterwards proved in this case. While it is quite possible to do the work in this way if the piers are braced and kept braced, there is a liability that the braces may be removed without the knowledge of those who realize the danger of their removal, as happened here. When one-half of the reservoir had been arched over in quarter-sections at a time, and the centers were being set for the third section, the center row of piers, or those supporting the outer edge of the finished half of the roof, were overturned, and the arches between them and the next row fell, killing one man, breaking the leg of another and slightly injuring two more. It was just after seven o'clock, and neither the contractor nor the inspector was present. It was found upon investigation that three and, as two of the carpenters testified, four out of five braces that resisted the thrust on this row of piers had

COMMONWEALTH OF MASSACHUSETTS.

State Board of Health. Wellesley.

WATER ANALYSIS.

PARTS IN 100,000.

	No.	Date of Collection.	Date of Examination.	Appearance. Turbidity.	Appearance. Sediment.	Appearance. Color.	Odor. Cold.	Odor. Hot.	Residue on Evaporation. Total.	Residue on Evaporation. Loss on Ignition.	Residue on Evaporation. Fixed.	Ammonia. Free.	Ammonia. Albuminoid. Total.	Ammonia. Albuminoid. In Solution.	Ammonia. Albuminoid. In Suspension.	Chlorine.	Nitrogen as Nitrates.	Nitrogen as Nitrites.	Oxygen Consumed.	Hardness.	Iron.	Remarks.
Water Not in Use	21741	1898. Jan. 3	1898. Jan. 4	Slight	Slight	.03	Faintly Mouldy	Distinctly Mouldy	10.20	....	....	.0428	.0186	....	....	.71	.2650	.0002	.12	4.3	0020	New Covered Reservoir
Water Not in Use	21917	Jan. 19	Jan. 20	Slight	Slight	.05	None	None	12.10	....	....	0762	.0344	....	....	.73	.2400	.0001	.24	3 8	.0010	
Water Not in Use	22096	Feb. 7	Feb. 8	Slight	Slight	.05	None	None	10.30	....	....	.0040	.0076	....	....	.70	.1850	.0003	.06	3.9	.0020	
In Use	22786	April 11	April 11	None	None	.01	None	None	6.90	....	....	.0002	0014	....	....	.57	.0830	.0000	.02	3.4	0060	
In Use	26037	1899 Jan. 25	1899 Jan. 26	None	None	.00	None	None	6 50	....	....	.0014	0042	....	....	.56	.0840	0000	01	3.1	0010	

The color of water is expressed by numbers which increase with the amount of color. Boston water, as drawn from a tap at the State House, had an average color in 1898 of 0.41. Other water supplies in the State had an averag e color of from 0 to 1 39.

All waters containing suspended matter, excepting ground waters which contain a large quantity of iron, are filtered through filter paper before determining the color and residue on evaporation. Occasionally these determinations are also made on the unfiltered water, the results in such cases being indicated by an asterisk.

been removed. It transpired afterwards that the braces had been removed from the first section in the same way, and the tensile strength of the concrete was sufficient to keep the arches intact. There was a greater load on the half-section, as a portion of the covering had been put on.

With the exception of this unfortunate accident, the work on the reservoir was very successfully carried out. The contractor, Mr. Donato Cuozzo, took a great personal interest in having the character of the work of the very best, and used every effort to make it so. When finished the reservoir was filled and allowed to stand for some weeks without any draft upon it; there was practically no loss of water from it. The effect upon the water, as shown by a chemical analysis, of standing without change in this new reservoir was marked. The cause of this has never been explained. The results of the analyses on the preceding page (made by the State Board of Health) show in what way it was affected.

A plan and section of this reservoir is shown in Fig. 1.

The reservoir has now been in use about fifteen months with satisfactory results. The final quantities, their contract price and the total cost of the reservoir, aside from any expense caused by the accident, are given below:

3446.20	cubic yards earth excavation	@ $0.40	$1,378.48
24.50	" " rock "	@ 2.50	61.25
309.80	" " rubble masonry	@ 3.10	960.38
502.86	" " concrete	@ 3.50	1,760.01
61.22	" " brick	@ 10.50	642.00
143.30	" " gravel	@ 1.00	143.30
484.50	square " plastering wall	@ .20	96.90
570.30	" " " floor	@ .20	114.06
438.60	cubic " loam in place	@ .20	87.72
	Setting pipes, gates, etc.		100.00
	Seeding and sodding		60.00
148.	vitrified pipe	@ .25	37.00
	Channel iron ring		350.00
	Bracing, sheeting and centers		500.00
	Payment to contractor		$6,291.91

In addition to the above there are the following items that were outside of the contract:

Portland cement	$3,156.18
Cast iron pipe, special castings, gates and gate boxes	464.32
Special ironwork	77.34
Hauling sod	21.38
Gravel in the pit	65.00
Carpenter work on brick house for telemeter	138.93
I beams for same	24.00
Telemeter transmitter and wiring	70.80
Blacksmith work	15.00
Sodding not done the first season about	90.00
Total of extra items	$4.122.95
Total cost	$10.414.86

THE DESIGN OF COVERED RESERVOIRS AND WATER FILTERS.

The controlling factors in the design of covered reservoirs for water or sewage and in that of the structure that contains the filtering materials or the filter bed in a water filter of the "sand filtration type," where the latter must be covered, are so similar that the design of both can very well be treated in the same paper. The following discussion of such design is intended to refer to both in so far as it relates to their common features. It will be readily perceived when the discussion refers to considerations peculiar to only one of the subjects, as, for instance, that in regard to the economic ratio of depth to area, which refers only to the reservoirs. For convenience, the word reservoir will be used in referring to the subject of the paper.

The required capacity of the proposed reservoir having been determined, which determination is independent of the design of the reservoir itself, its form is naturally the first question to be considered. If the choice is not restricted by topography or property lines, either the square or circular form would naturally be chosen. Which of these is the more economical may depend upon local conditions, the relation of depth to area, or to other factors in the case. The natural inference is that the circular form would require less materials in its construction. Where land is expensive the square one might be the cheaper. The cost of each type under various conditions will be given in this paper. As the form departs from the square or the circle the cost increases for the same capacity, since the length of the side walls is greater in proportion to the inclosed area; therefore economical design does not permit a departure from these two forms except where it is rendered necessary by the shape of the lot or the topography of the ground.

The relation of depth to area must next be determined; there seems to be nothing to indicate with any certainty what this ratio may be. The amount of excavation is about the same for any ratio; the cost of the roof, floor and piers will increase directly with increasing area; the cost of the side walls increases about as the square root of the area. On the other hand, an increase in depth involves an increase in the cost of the walls, which is greater than that of their depth, owing to the increasing thickness of the bottom. In an absolutely scientific design the material in the piers will increase faster than their depth, due to the necessity of making their horizontal dimensions greater as their length increases. If not altogether impossible, it would be very difficult to construct a formula that would combine all of these factors and give the economic ratio. An endeavor will be made in this paper to pro-

vide a means of ascertaining this ratio for certain types of reservoirs without having recourse to the tedious method of designing and estimating upon several reservoirs of different dimensions. In the discussion of the design of a reservoir the several parts will be treated separately.

ROOF, OR VAULTING.

The design of the vaulting is more independent than that of the other parts, and their design is largely influenced by it; therefore the first consideration will be given to it. This paper is intended to treat wholly of masonry or imperishable construction, and no attention will be given to roofs of other types, although such may be quite satisfactory under some conditions.

The choice of material for the arches is practically confined to two kinds. Brick is the material of which most of the covering arches have been made. The use of concrete is increasing rapidly at the present time, and, when properly made with Portland cement, it cannot be surpassed. Its cost per cubic yard is about one-half that of brick masonry, and it is not necessary to use a greater quantity than of the latter. However, either makes an excellent vaulting, and the choice may often depend upon the local availability of the material. Concrete was used in the arches of the Wellesley reservoir, and in one built by Mr. F. L. Fuller for the State Hospital for Epileptics at Palmer, Mass. The vaulting of filter beds built by Mr. Allen Hazen at Albany is also of the same material. A sewage reservoir that is being built at Clinton by the Metropolitan Water Board is to be covered with concrete. As concrete can be placed in any form with little trouble, almost any type of arch may be selected. Consideration must of course be given to the comparative difficulty of making the centers.

Groined elliptic arches offer many advantages: the quantity of the material required is small; there is a clear head room in each direction, which is not the case with barrel arches; and the arrangement is good for ventilation. With groined arches both lintel arches and iron girders are avoided. This type was adopted by Mr. Wm. Wheeler in the composite brick and concrete arches of the filter beds at Ashland, Wis., and Somersworth, N. H. It was also adopted for the concrete arches of the Wellesley and Clinton reservoirs, and by Mr. Hazen for the Albany filters. The dimensions of the arches in the first two instances were as follows: Clear span 13.75 feet, rise 3.50 feet, thickness at crown about 5 inches, or the thickness of two bricks laid flatwise. By a curious coincidence, which was the result of independent study, the Wellesley and Albany arches have exactly the same dimensions,—namely,

clear span 12 feet, rise 2.50 feet, thickness at the crown 0.50 feet. In the Clinton reservoir the span and rise is to be the same, and the thickness of the crown is to be 1 foot. The thickness of the earth covering is about twice as great as in the other cases. This study of design will be limited to elliptical groined arch vaulting, with especial reference to the use of Portland cement concrete.

The determination of the unit pressures is rather uncertain. When built of concrete, and to a certain extent when built of brick in cement, an arch of this form is monolithic, and a portion of the internal stress is resisted by the tensile strength of the material, instead of being wholly in compression, as in a barrel arch. The stresses, in a section of the arch normal to the axis and in line with the piers, are probably compressive in as far as they are caused by the load upon that section. Since there is no diagonal rib or arch

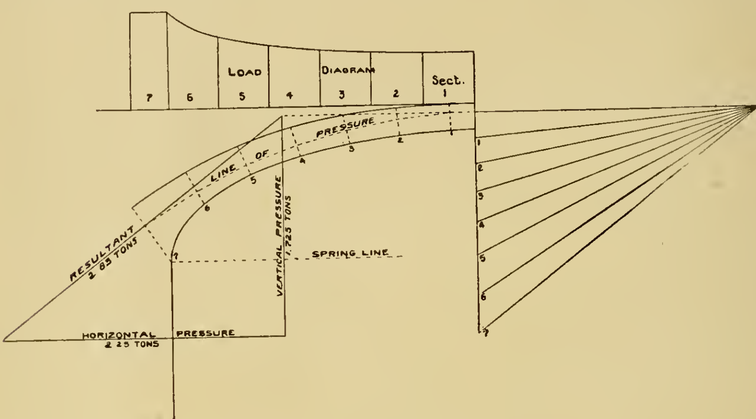


FIG. 2.

at the groin to carry the pressures caused by the load on the flanks of the arches to the piers, these pressures must be distributed by the tensile strength of the material between the normal arch and a certain portion of the groin in a way that would seem to defy mathematical treatment.

It is impossible, however, to secure a bond between new work and that already set, in which the adhesion of the new to the old is equal to the cohesion in the body of the material. In work of much extent such bonding cannot be avoided. Contraction cracks are also quite sure to occur in large areas of masonry. In view of these considerations, it is probably wise to neglect the tensile strength, or at least give it but little weight, and, if any consideration is to be given to computed pressures, to calculate them approximately, under the most unfavorable conditions.

The load on the arches is their own weight, that of the earth covering, the water that it holds in saturation, ice and snow and whatever load of people may come upon it. As a distributing reservoir is usually in a sightly place, the last item must be given due weight, unless thorough provision is made to exclude them.

Fig. 2 shows a section, normal to its axis, of an arch with a clear span of 12 feet, rise of 2.50 feet and thickness at crown of 0.50 feet; also a graphical representation of the pressures in a unit section of 1 foot. These dimensions are taken as being identical with two recent examples actually built, with the exception of the thickness, of one that is being built and because there seem to be reasons for using about these dimensions. (The latter is opinion only, and cannot be demonstrated except by a great deal of work in designing and computing those of different dimensions and estimating their effect upon other parts of the reservoir.)

Table No. 1 gives the loads, and Table No. 2 gives the unit pressures at the different points of the arch shown in Fig. 2.

TABLE NO. 1.

Loads on Normal Arch.

No. of Sect.	Area of Concrete, Sq. Ft.	Wt. of Concrete, Lbs.	Wt. of Earth, Lbs.	Wt. of Snow and Ice, Lbs.	Wt. of People, Lbs.	Total Weight, Lbs.	Total Weight, Tons.
1	0.52	78	250	25	50	403	.202
2	0.60	90	250	25	50	415	.207
3	0.72	108	250	25	50	433	.216
4	0.97	145	250	25	50	470	.235
5	1.34	201	250	25	50	526	.263
6	1.98	297	250	25	50	622	.311
7	2.25	337	187	19	38	581	.290

Total load on one foot section of half-arch 1.724

TABLE NO. 2.

Average Unit Pressures on Normal Arch.

No. of Joint.	Total Press. on Joint, Tons.	Area of Joint, Sq. Ft.	Average Unit Pressure per Sq. In., Lbs.	Average Unit Pressure per Sq. Ft., Tons.
1	2.26	0.50	62.80	4.52
2	2.29	0.53	60.	4.33
3	2.33	0.56	57.60	4.15
4	2.41	0.59	57.	4.10
5	2.52	0.62	56.	4.03
6	2.67	0.70	53.	3.81
7	2.90	1.33	30.20	2.18
At crown	2.25	0.50	62.50	4.50

As the arch proper and the spandrel filling are one mass, in computing the pressures the extrados of the arch must be assumed. In Fig. 2 a thickness was found by trial in which the unit pressures would nowhere exceed that at the crown, and in which the line of pressure would lie wholly within the middle third. The average unit

pressure at the crown is 4.50 tons, and as the line of pressure at this point is one-third of the thickness from the outside; if the material is considered as inelastic the maximum unit pressure will be twice the average, or 9 tons. This is probably the greatest pressure in the arch. The line of pressure is also at one-third of the thickness from the soffit near the point called joint 5. At all other points the line of pressure is well within the middle third, and the maximum pressures are less. There seems to be no way in which the unit pressures in the groin can be determined with much precision, as there is no separate rib or arch in which to compute them. If a width is assumed for a rib the pressures in it are modified by the tensile strength of the material of which it is a part; this must prevent the result from being even approximately correct. The unit pressures at and near the groin are probably slightly in excess of those in the normal arch. This opinion is based upon some rough approximations. It is, however, hardly worth while to make elaborate calculations to find these

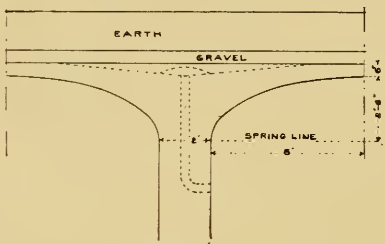


FIG. 3.

pressures; there are several examples of this type of arch with a thickness of 6 inches at the crown in actual existence. If it is desired to make a saving in material from that required by this thickness, it will be better to depress the filling over the piers and leave the crown thickness 6 inches. The arches of the Albany filters were made with such a depression; this is shown by the dotted lines in Fig. 3. This depression was filled with clean gravel and drained into the filter by pipes set in the piers. These pipes are also shown by dotted lines in Fig. 3.

Where it is permissible to drain the water that seeps through the earth covering, to the inside, this is in some respects better than a flat surface; some concrete is saved without weakening the arch, and the drainage of the top of the vaulting is freer.

The amount of material in cubic yards in vaulting when constructed as shown in Fig. 3 is given in Diagram No. 1. This is designed to give the quantity within the inside lines of the side walls for different dimensions of square and circular reservoirs

($2\frac{1}{2}$ per cent. excess is allowed to cover variations). The cost per cubic yard of concrete in the vaulting is probably no greater than in other parts of the reservoir if the cost of the centering is not included, but treated as a separate item. The cost of the centers, their supports, placing and removing them, is from 15 to 20 cents per square foot for the interior surface of the reservoir if it is all centered at once. If it can be centered and covered in sections the cost of centering will be greatly reduced.

EXCAVATION AND EMBANKMENT.

When it is possible to do so, as it usually is in a distributing reservoir, economy demands that the material from the excavation shall be approximately sufficient to make the embankment. For ordinary conditions Fig. 4 shows a good design for the embankment of either a square or circular reservoir, or for a filter that is partially in embankment.

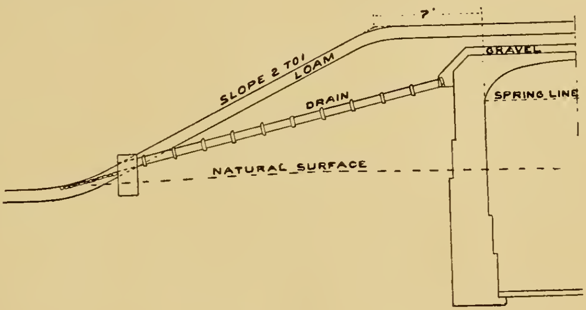


FIG. 4.

Diagram No. 2 gives the quantities of excavation and embankment in square and circular reservoirs of different depths and dimensions.

Trial computations to determine the elevation at which the excavation will balance the embankment are usually tedious. A few minutes' work with Diagram No. 2 will determine this so nearly that one check computation will enable it to be fixed as nearly as it is possible to do. If the site is level the results from the diagram are correct; if it is not level, take the average elevation of the ground to be covered by the reservoir and its banks, and the result will be approximately correct. One exact computation will then show whether it should be raised or lowered a trifle. Ten per cent. is allowed in the diagram for shrinkage. The method of finding the elevation, or, in other words, the depth below the average of the surface, that the bottom of the reservoir should be placed is as follows: After the required horizontal dimension and

total depth are determined, find on the lines of the diagram, which represent the diameter of a round reservoir, or the length of side of a square one, a depth of excavation and a height of embankment that both fall upon the same horizontal line representing quantity in cubic yards, and together equal the total depth of the reservoir from the floor to the water line. Note.—When reading quantities in excavation the scale for diameter or length of side must be read at the bottom of the diagram, this scale reading from right to left; while the dimensions must be read at the top when quantities in embankment are required, this scale reading from left to right.

Generally more than one trial will be necessary to find a depth of excavation and height of embankment the sum of which will just equal the total depth of the reservoir, somewhat as follows: If a proposed circular reservoir is to be 100 feet in diameter and 15 feet deep, assume for first trial that the depth of excavation will be 8 feet. Then on the diagram at the left, for round reservoirs, find the intersection of line for 8 feet depth with that of 100 feet diameter; read on the bottom scale. At this intersection the horizontal line has a value of 2960 cubic yards. Following this line across to the line for 100 feet diameter on scale for embankment, read at the top, we find that value of the curve for embankment intersecting at this point is 6 feet below the water line. Therefore, the total depth of a reservoir that an excavation of 8 feet would provide embankment for is 8 plus 6, or 14 feet; but the required depth is 15 feet, and another trial must be made. Less than 1 foot must be added to the 8 feet of the first trial. Trying 8.6 feet as nearly as it can be read, following the same process as before, we find 3160 yards of excavation and a trifle less than 6.5 feet for the embankment below the water line, making a total of practically 15 feet. Owing to the uncertainty in the actual shrinkage of any soil, a determination within one- or two-tenths of a foot is near enough for practical purposes. The actual amount of the embankment measured in place will, of course, be only 90 per cent. of that read from the diagram, as that includes the 10 per cent. for shrinkage.

N. B.—Depth of reservoir or "depth" when used in the diagram always means the depth of water from floor to high water line.

If the reservoir is located in a hollow, the excavation will be some less than the diagram gives, using the average elevation of the ground. If on a knoll, and probably if on a slope, it will be more. A trial location by the diagram and one check computation will enable the elevation to be fixed. If the reservoir is wholly in

excavation, the amount will be found on the diagram by using the depth from the surface to the inside bottom of the reservoir.

SIDE WALLS.

The side walls should be vertical, or nearly so, in order that the vaulting shall have to cover as little area as possible. The ordinary practice in the design of dams or retaining walls is not applicable to these walls. Being supported outside by the earth, they are not like a masonry dam. The thrust of the vaulting resists the tendency of the wall to rotate on its toe; therefore they are unlike retaining walls. If the masonry were homogeneous, the wall of a square or rectangular reservoir would act as a beam, with the roof and floor as supports; but it is improbable that the bonding of the horizontal joints would be sufficiently good to prevent

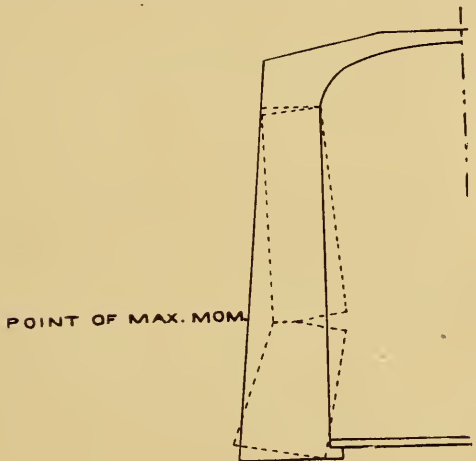


FIG. 5.

failure. When, however, the point of failure is reached, in order for it to proceed a crack or joint must open on the inside of the wall. If the material is assumed to be rigid, either the part of the wall above the break and the load upon it must be raised or the lower portion must be pressed into the earth with a force equal to the load above to allow the crack to open. In this case the moment of the external forces acting upon the wall is resisted by that of the weight into its lever arm.

An examination of Fig. 5 makes it evident that the whole wall must be raised, but, as one edge is supported, only one-half of its weight resists forces tending to lift it; the weight of the half-arch of the roof with its load must also be raised. If it is assumed that

the material is not rigid, but will be crushed or tend to be crushed on the edges on which the two parts rotate, the weight must still be raised; but the lever arm of the weight will be shortened by so much of the thickness of the wall as will sustain the weight above the break without exceeding the strength of the material. In a reservoir that is to be emptied occasionally, the maximum outside pressure on the wall would be that due to water remaining in the earth behind the walls. With a reservoir partly in excavation the height of this water could not exceed the high-water line of that inside, while in one wholly underground it might be at the surface, or even above it, if the site were occasionally flowed. The maximum moment of this pressure, assuming that the water outside is

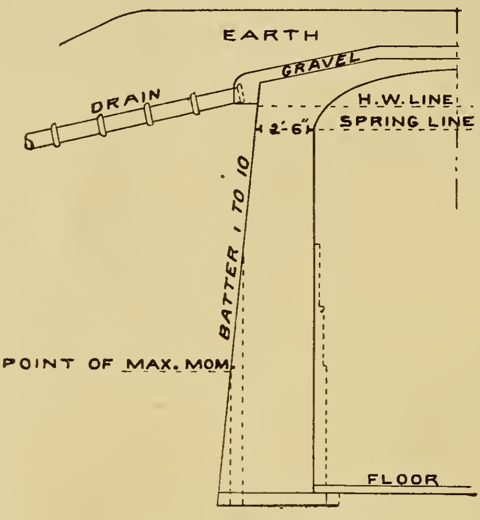


FIG. 6.

at the spring line of the roof arches, is at one-third of the height of the wall from the bottom; its amount in foot-pounds is that due to a load distributed in the form of a triangle, whose base is equal to the height of the wall and whose perpendicular is equal to the height in feet into the weight of water per cubic foot.

The foregoing refers to straight walls only; in the walls of round reservoirs the outside pressure is resisted by the wall as an arch. If this pressure is assumed to be due to the water in the earth backing, it will be uniform all around, and the maximum pressure at any point will not exceed one-half the product of the unit pressure by the diameter. The total pressure will increase with the depth and the diameter until dimensions are reached for which the thickness must equal that for straight walls. For greater dimen-

sions they must be designed to meet the conditions of the latter. The thickness of the top of the wall is not governed by these considerations. The thrust of the roof will largely determine this thickness. On straight walls, as shown in Fig. 6, the horizontal thrust of the roof is approximately 2.25 tons per lineal foot. Neglecting the adhesion of the mortar, there are two factors of resistance to this thrust,—that caused by the friction of the wall and its load on any joint or place in the wall where movement would take place, and that due to the embankment above such joint. With a thickness at the spring line of 2½ feet, as shown in Fig. 6, the sum of these two elements of resistance, above a point in the wall where the resultant pressure of the arch and the wall above this point passes through the outside of the middle third, is about 1.9 times as great as the horizontal thrust of the roof, or a factor of safety of nearly two.

With circular walls in which the groined arch must be carried out to the wall at most points and can be at all, the average horizontal thrust is not so great as in straight ones, being about 1.75 tons per lineal foot. The resistance of the embankment above the spring line is about 2 tons, or 1.15 times the thrust. It is easy to increase this resistance by a ring of steel imbedded in the wall above the spring line; therefore it is not necessary to thicken the wall, as the roof exerts only a vertical pressure upon it. Its thickness will then be determined by the requirements of practical construction; all of these will be met by a thickness of 2 feet at the spring line.

As examples of existing walls with this type of roof, the two following are straight walls. Those of the filter beds at Ashland, Wis., are 2 feet thick at the top, and have a batter of about 1 in 10. These are either wholly in excavation or have an embankment 15 feet wide, supported by a braced pile trestle. The walls of the Albany filters are in embankment, are 2½ feet at the top and have a batter of 1 in 10. For circular walls, those of the Wellesley reservoir are 2 feet thick at the top. The walls of the sewage reservoir at Clinton are to be 2 feet at the top and have a batter of 1 in 10.

A steel ring was imbedded in the walls of the two last-named reservoirs. In the Wellesley reservoir, which was 82 feet in diameter, this ring was made of a channel iron weighing 32 pounds per foot. In the one at Clinton it is to be in three parts or rings of flat iron. The reservoir is 100 feet in diameter, and the total weight of the rings per lineal foot is 30 pounds. This seems to be a better arrangement of the steel than the channel iron, as the joints or splices in the different rings can be "staggered" and loss

of strength in the total section reduced to that in one ring, and it can probably be furnished and placed at a lower rate per pound.

Fig. 7 shows the arrangement of such rings in the section of the wall. The following table gives the required weight for reservoirs of various diameters per lineal foot and the total weight. The weights given are designed to provide a factor of safety of three in the resistance to the thrust of the vaulting, including the resistance of the earth embankment. Note.—In computing the resistance of the embankment and the wall to sliding a co-efficient of friction of 0.80 was taken for earth; of 0.65 for masonry. The weights of the following table are also given on Diagram No. 1, which will give other diameters than those in the table:

TABLE No. 3.

Weight of Steel Ring.

Diameter in Feet.	Weight in Lbs., per Lineal Foot.	Total Weight in Lbs.
50	14.5	2,280
60	17.4	3,280
70	20.3	4,460
80	23.3	6,850
90	26.2	7,380
100	29.	9,120
125	36.3	14,300
150	43.5	20,600
175	50.8	28,000
200	58.	36,500

Formula for dimensions not in table: Weight per lineal foot $=$ 0.29 Diam. Total weight $=$ 0.912 Diam.^{2}

In the above table 25 per cent. is allowed for splicing and rivets; therefore, to find the weight of the net cross-section take 80 per cent. of the above weights per lineal foot.

In the construction of the walls satisfactory results can be secured by the use of either concrete or rubble masonry of sound angular stones of any sizes that are not large enough to go entirely through the wall. Exceedingly good work can be done with small stones by laying the face of the wall up to a form and bedding the stone thoroughly in the mortar without regard to bonding, making a coarse concrete in fact. All smooth, rounded stones should either be broken or thrown out. Portland cement should be used for this work, as it should be for all of the work in these reservoirs. Natural cement may, of course, be used, but as strength is required rather than weight the cost of equally satisfactory work will be greater than with Portland cement. The choice of concrete or rubble will probably depend upon the kind of material which is the most available.

Diagram No. 3 gives the amount of masonry in the side walls of square and round reservoirs. This diagram is computed from the sections shown in Figs. 6 and 7, and includes all of the masonry from the under side of the foundation to the extreme top of the wall. "Depth," as before, means depth of water. These sections are sufficient for reservoirs of the dimensions given on the diagram, and are uniform for all. They could perhaps be made lighter for the smaller sizes and depths of the round reservoirs if it was considered desirable to do so. For preliminary estimates it is hardly worth while to make any changes from the quantities given on the diagrams. The following tables give the approximate unit pressures that the maximum outside pressures bring upon the masonry when calculated in the manner already indicated:

TABLE No. 4.

Straight Walls.

Height of Wall.	Maximum Moment.	Weight of Wall to be Raised.	Necessary Length of Lever Arm.	Thickness of Wall at Point of Max. Moment.	Thickness Remaining to Resist Crushing.	Total Pressure on Masoury.	Max. Unit Press. Tons per Sq. Ft.
Col. 1	2	3	$4=\frac{2}{3}$	5	$6=\frac{5}{4}$	7	$8=\frac{7}{6}$
5 feet....	0.180	2.62	0.07	2.80	2.73	2.40	0.88
10 "	1.50	3.24	0.47	3.20	2.73	2.80	1.03
15 "	4.78	4.10	1.17	3.50	2.33	3.20	1.38
20 "	11.25	4.80	2.35	3.80	1.45	3.80	2.62
25 "	22.00	5.60	3.93	4.20	0.27	4.30	16.00

TABLE No. 5.

Circular Walls at Depth of 25 Feet.

Diameter.	Total Pressures at Bottom on Section One Foot High.	Cross-Section in Square Feet.	Maximum Unit Pressure per Square Foot.
Col. 1	2	3	$4=\frac{3}{2}$
50................	19.5 tons	4.50	4.33 tons
75................	29.6 "	4.50	6.57 "
100................	39.05 "	4.50	8.67 "
125................	48.80 "	4.50	10.85 "
150................	58.50 "	4.50	13.00 "
200................	78.00 "	4.50	17.35 "

Although the extreme pressures in the tables may be considered rather high for rubble and concrete, it must be remembered that they could only occur if the water in the earth backing remains at the high-water line until the reservoir is wholly emptied. This would be a rare condition in an embankment, and may be avoided entirely if desired. The method of doing this will be referred to hereafter.

The pressure of the water in the reservoir tending to force the wall outward must be resisted by the earth backing, otherwise the wall must be designed as a dam. If this were necessary, all of such

walls that are existing to-day would have failed. If there is a slight yielding in the earth, it is probably compensated by some elasticity in the masonry. It is of the utmost importance, however, that the backing be deposited in very thin layers and thoroughly rammed. If the nature of the excavation is such that it will stand vertically or nearly so until the wall can be built, it is desirable to make the lower part of the latter without batter or offset on the outside to as high a point as possible and to lay the masonry solidly against the undisturbed earth. If the theory of the resistance of straight walls that is adopted in this paper is correct, they may be built with a vertical back from the point of maximum moment (at one-third of their height) to the bottom without loss

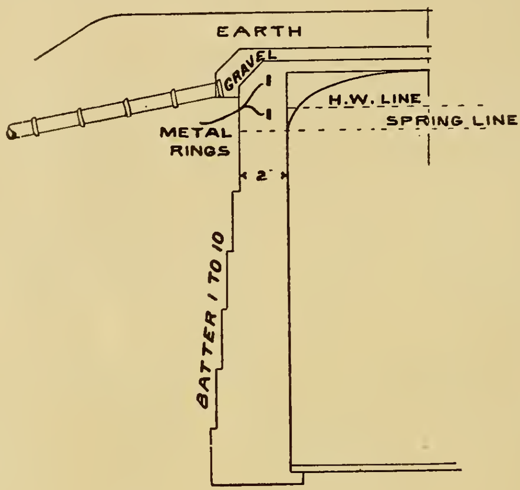


FIG. 7.

of strength. Fig. 4 shows how circular walls may be built to secure a vertical line in the lower part of the wall; there will generally be no objection to the interior offsets, and in filters they are desirable in order to avoid a direct line for the water to follow from top to bottom.

There is one more factor to be considered in the design of straight walls; that is the tendency of the wall to slide into the reservoir. Following the idea that the wall is a loaded beam, the tendency to slide must be met by a reaction at the top equal to one-third of the total load on the wall, and at the bottom to two-thirds. Assuming water pressure at the back as before, the loads and reactions are as follows:

TABLE NO. 6.

Reactions at Top and Bottom of Straight Walls.

Height of Wall.	Total Load.	Reaction at Top.	Reaction at Bottom.
5 feet...........	0.39 tons	0.13 tons	0.26 tons
10 "	1.56 "	0.52 "	1.04 "
15 "	3.50 "	1.17 "	2.33 "
20 "	6.23 "	2.08 "	4.15 "
25 "	9.75 "	3.25 "	6.50 "

There are three factors of resistance to sliding at the bottom of a wall such as shown in Fig. 6,—the friction of the wall on the earth, the resistance to compression of the concrete floor and of the earth inside of the foundation under the floor. With a floor 4 inches thick and wall foundation 6 inches deep, with co-efficient of friction of the wall on the earth of 0.65 and safe pressures on the earth and floor concrete of 2½ and 10 tons per square foot, respectively, the total resistance for a unit section 1 foot long is given in Table No. 7:

TABLE NO. 7.

Resistance to Sliding of the Bottom of Straight Walls.

Height of Wall.	Friction on Earth.	Resistance of Concrete.	Resistance of Earth.	Total Resistance.	Reaction at Bottom.	Excess of Resistance.
5 feet......	1.76	3.33	1.25	6.34	0.26	6.08 tons
10 "	2.27	3.33	1.25	6.85	1.04	5.81 "
15 "	3.05	3.33	1.25	7.63	2.33	5.30 "
20 "	3.83	3.33	1.25	8.41	4.16	4.25 "
25 "	4.62	3.33	1.25	9.20	6.50	2.70 "

These figures indicate that such walls under 25 feet in height will not fail by sliding at the bottom. They will not fail at the top if the thickness is sufficient to prevent shearing. The reaction at the top of a 25-foot wall is 3.25 tons. The section to be sheared in a wall 2½ feet thick at the top is 360 square inches per lineal foot, or a stress of about 19 pounds per square inch. There are no data on the shearing strength of concrete; it seems, however, that it must be greater than the tensile strength, and that the above must be a safe figure for that of good concrete or rubble in Portland cement. The above stresses only occur in a reservoir that is just emptied.

NOTE.—As the thrust of the vaulting against the wall in the proposed design is but 2.25 tons per lineal foot, if the required reaction at the top must exceed that amount in order to resist the outside pressure, the load on the vaulting must be made heavier and the vaulting stronger to provide the required reaction.

PIERS AND THEIR FOUNDATIONS.

The maximum load upon each pier with the roof shown in Fig. 3 is about 46 tons, the piers being 14 feet apart on centers in

each direction. Piers can be built of either brick or concrete. The great majority of existing piers are of brick, very few of concrete being on record. There seem to be practical reasons for the use of brick. The amount of material is not large, and it is probable that the expense of making and setting forms for concrete will make its cost as great in this class of work.

The allowable unit pressure for Portland cement brickwork is not definitely determined. Baker, in his book on "Masonry Construction," gives about 30 tons per square foot as a general estimate. In a pier, however, the relative dimensions should be considered in its design. There is a wide diversity in practice, as shown by existing examples. The following table gives the dimensions and unit pressures in several modern reservoirs:

TABLE NO. 8.

Dimensions and Pressures on Piers.

	Piers			Roof Surface			
Reservoir.	Height, Feet.	Section, Square Feet.	Cross-Section Divided by the Height.	Area, Square Feet.	Approx. Weight, Tons.	Unit Pressure, Tons.	Unit Pressure Multiplied by Length of Pier.
Newton	13.5	2.78	0.205	136	32.	11.5	155
Brookline	17.5	4.00	.228	144	26.5	6.63	116
Franklin	16.5	1.00	.061	90.5	20	20	330
Ashland	5.0	4.00	.80	248	54	13.5	67.5
Wellesley	12.25	4.00	.325	196	51	12.75	156
Albany	7.5	2.78	.370	187	41	14.75	111
Clinton	7.0	4.00	.572	210	78	19.5	136
Proposed	7.0	2.78	.398	196	46	16.55	116

The height of piers given in the above table is not in every case the total height from the floor to the spring line, but the length between offsets. The piers in the first three cases had no offsets, but were uniform in size from top to bottom; in all of the others the bases of the piers were enlarged, and in the Clinton reservoir and the proposed design the top is also enlarged by offsets. It is very desirable to spread the base in order to distribute the strains over as large an area of the top of the foundation as possible, so that it may be made thinner and still not overload the earth below. Where the unit pressures are high it is also desirable to spread the top of the piers, so that they may not be so great in the concrete at the spring line. A neat and economical design for piers is to make the body of the same size for all heights, and make the offset portion at the bottom (and at the top if desirable) longer as the total length of the pier increases, keeping the length of the body the same for all heights of reservoir.

Fig. 8 shows a pier of this design. The body of the pier is 20 inches square, and for heights of 8.25 feet and over its length is 7 feet. The base increases in height, but not in bottom area, as the

pier is made longer. Diagram No. 4 gives the amount of brickwork in such piers for different sizes of round and square reservoirs. These quantities are based upon the areas of the reservoirs, and are not precisely correct for some dimensions, but are nearly enough so for preliminary estimates. The following table gives the exact amount for one pier, and, if closer results are desired than the diagram gives, the exact number of piers can be obtained from a plan and the quantities from the table used:

Table No. 9.

Brickwork in Piers of Various Heights from Floor to Water Line.

Note.—This height is 1 foot greater than the actual length of the pier.

Height of Reservoir.	Brickwork, Cubic Yds.	Height of Reservoir.	Brickwork, Cubic Yds.	Height of Reservoir.	Brickwork, Cubic Yds.
5 feet	0.62	12 feet	1.62	19 feet	3.01
6 "	.72	13 "	1.82	20 "	3.20
7 "	.83	14 "	2.03	21 "	3.40
8 "	.95	15 "	2.24	22 "	3.60
9 "	1.10	16 "	2.45	23 "	3.79
10 "	1.27	17 "	2.64	24 "	3.98
11 "	1.45	18 "	2.83	25 "	4.17

Piers should be built of the best of brick, in respect to the qualities of hardness, homogeneity and uniformity of shape and dimensions. They should be laid with absolutely full joints in Portland cement mortar as closely as the brick can be laid and the joints neatly struck with a jointing tool.

PIER FOUNDATIONS.

Pier foundations should be designed to transmit the pressure from the piers to the earth uniformly, with a unit pressure that is safe for the character of the ground. The following table is taken from Baker's "Masonry Construction":

Table No. 10.

Safe Bearing Power of Soils.

Kind of Material.	Tons per Sq. Ft. Minimum.	Maximum.
Clay in thick beds, always dry	4	6
Clay in thick beds, moderately dry	2	4
Clay soft	1	2
Gravel and coarse sand, well cemented	8	10
Sand, compact and well cemented	4	6
Sand, clean and dry	2	4
Quicksand, alluvial soils, etc	0.5	1

The soil in most sites of reservoirs for water supplies would be as strong as sand, compact and well cemented, and could be loaded with 4 tons per foot. Sewage reservoirs and filter beds might often

be on less secure foundation. Each case must be considered on its merits. Having determined the horizontal dimensions by reference to the allowable unit pressure on the soil, the depth or thickness of the foundation depends upon its size and that of the bottom of the pier that rests upon it. The thickness will probably be sufficient if a line drawn from the outside edge of the bottom of the pier to the bottom edge of the foundation has a batter of not more than 1 to 2; thus, if the foundation is 6 inches larger each way than the bottom of the pier, its thickness should be not less than 1 foot. With good Portland cement concrete this would distribute the pressure over the entire bottom of the foundation. From Diagram No. 1 the quantities may be taken for the pier foundations

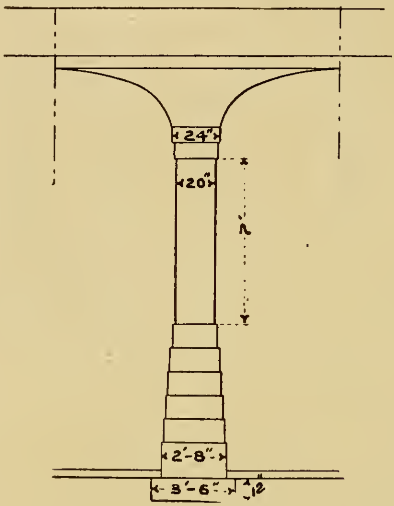


Fig. 8.

shown in Fig. 8, which were designed on the foregoing principles to carry the roof and the load that has been described. The estimated pressure on the soil in this case is about 3.8 tons.

FLOOR.

There should be a smooth concrete floor in all covered reservoirs. Its thickness is dependent upon the conditions of the particular reservoir. If the material in which it is built is such that there is little danger of outward leakage, and there is no likelihood of an upward water pressure to lift the floor when the reservoir is emptied, a thickness of 3 or 4 inches is sufficient. The reservoirs at Brookline, Newton and Wellesley had floors 4 inches thick; the floor of the Ashland filter was 3 inches. If, on the contrary, the

earth is pervious, and the movement of water when the reservoir is full will be away from it, the floor should be at least 6 inches. From his experience in the construction of and subsequent observation of a number of open reservoirs, also from experiments on concrete of different thicknesses, the writer believes that with heads of 20 feet and under 6 inches of good Portland cement concrete is, or becomes in a short time, very effective in preventing seepage. It should be plastered or finished with rich cement mortar. An excellent method for floors is to finish the concrete as soon as it is rammed, before it begins to set, with mortar mixed for the purpose. If a surplus of water stands on the concrete after ramming, good work can be done by spreading dry cement on and working it to a smooth, close surface with trowels. The liability of separation and peeling off which exists in plastering that has been done after the concrete has set is thus avoided.

If, when the reservoir is emptied, there will be an upward pressure on the floor, it must be designed to resist it. For this purpose inverted arches may be used, designed to carry the estimated pressure to the piers. The roof arches may be reversed, or the feet of the piers given a greater spread and flat circular arches used. In designing to resist the upward pressure care must be taken that the weight of the reservoir and its earth covering is greater than that of the water displaced, to avoid flotation when it is empty.

The Clinton reservoir is designed to resist this tendency to float, as it is anticipated that at certain seasons the outside water will stand above the reservoir and its earth covering. The latter is made 4½ feet thick to provide the necessary weight. The floor is a series of inverted arches. Where there is no sanitary objection, drainage can be arranged in such a way that there will be no upward pressure when the reservoir is drawn down. With a thin layer of clean gravel or broken stone, and underdrains if necessary, the water under the floor can be collected in a well, and through a pipe tightly set in the concrete floor be delivered into the reservoir when the pressure in the latter is less than that outside. An inward opening flap or check valve must be placed upon the pipe to prevent a loss of water from the reservoir. If drains were carried up the back of the wall, the pressure on the latter would also be relieved.

This arrangement would be undesirable in a sewage or other reservoir, the contents of which must be pumped or treated, as the amount would be increased by a flow from the outside.

PLASTERING.

To prevent leakage from the reservoir, and to secure a smooth surface that will be easy to clean, the inner face of the side walls should be plastered. The best results can be had with two coats, one of mortar, 2 parts sand to 1 of cement, laid on as thick as it will stay to even up the inequalities of the wall. This coat should not be smoothed. The last coat to be of neat cement $\frac{1}{8}$ to $\frac{1}{4}$ inch thick, thoroughly rubbed on with a trowel and nicely smoothed. If there is an outside pressure from water in the ground, it must be reduced by pumping during the plastering and until it is set. Under such conditions the outside should be plastered, if for any reason it is desirable to permanently exclude the ground water.

Diagram No. 5 gives the number of square yards of the plastering on the walls of reservoirs of different dimensions. The depths for which the diagram is figured is that from the floor to the high-water line.

MISCELLANEOUS ITEMS.

There are a number of items that will vary in different reservoirs. Among these are the piping, gates, manholes, ventilators, ladders and, if an automatic recording gauge is used, a small building and the apparatus itself. The cost of these items will be from 7 to 12 per cent. of the total. Seeding and sodding the top and slopes are included in the above.

TOTAL COST OF RESERVOIRS.

On the diagrams that accompany this paper are given the quantities of the material in the different parts of the reservoirs of the type described in the paper and shown on the sketches. With some of them there is a multiplying diagram by which the cost of such quantities at various prices per unit may be found. With the diagrams an estimate of the quantity of material and the cost of a reservoir of any dimensions within the limits of the diagrams can be readily made that will be correct for this type. A slight change in design, as, for instance, different spacing of the piers or minor changes in the form of the parts, will not materially affect the estimate.

For making preliminary estimates with even less work than the above entails, and for rapidly determining the economic ratio of depth to area for any desired capacity, Diagram No. 6 has been prepared for round reservoirs and No. 7 for square ones. These diagrams give the capacities in gallons and the cost in dollars for all of the dimensions within their limits. They were prepared by

taking the sum of the cost of all of the items at the unit prices given in Table No. 11, and adding 10 per cent. to this sum for the miscellaneous items. The value of this diagram in finding the economic ratio of depth to horizontal dimensions is not limited to this type, as this ratio will be approximately the same for others. It is believed that it will be found useful in preliminary estimates for other types and at other unit prices by applying such corrections as the engineer believes to be necessary.

Table No. 11.

Unit Prices of Quantities in Covered Reservoirs.

Earth excavation	per cubic yard	$0.50
Rubble or concrete in walls, pier foundations and floors	" " "	6.00
Concrete in roof	" " "	6.50
Brickwork in piers	" " "	13.00
Plastering walls	" square "	.25
Plastering floor	" " "	.15
Gravel on roof arches	" cubic "	1.00
Steel ring	per pound in place	.05
Centers, etc.	per square foot for total area of reservoir	.15

Table No. 12 gives the cost of certain capacities of reservoirs when built with economic dimensions. Caution.—As prices have risen materially since Diagrams 6 and 7 were prepared, it is probable that a percentage should be added to the results for present use.

It is perhaps needless to caution the reader against using the designs or the quantities given in the paper unless the conditions are substantially similar to those described, or until proper modifications are made.

Table No. 12.

Cost of Covered Reservoirs when Built with Economic Dimensions.

Capacity.				Taken from Diagrams 6 and 7.		
	Round Reservoirs.			Square Reservoirs.		
Gallons.	Diam.	Depth.	Cost.	Diam.	Depth.	Cost.
250,000	60	12	$4,700	54.5	11	$4,800
500,000	75	16	7,800	69.5	14	8,100
750,000	88	17	10,500	79.5	16	11,000
1,000,000	98	18	12,850	88.5	17	13,550
1,250,000	106.5	19	15,200	99.5	17	16,050
1,500,000	115.5	19	17,550	106	18	18,400
1,750,000	120	21	19,950	111.5	19	21,700
2,000,000	125	22	22,000	118.5	19	22,900
2,500,000	134	24	26,200	130	20	27,300
3,000,000	144	25	30,200	142.5	20	31,450
4,000,000	*166	*25	37,900	153.5	23	39,500
5,000,000	*186	*25	45,600	*165	*25	47,400

*These are not the economic dimensions. The diagram does not give greater depths than 25 feet. Moderate departures may be made from the economic dimensions, in either direction, without greatly increasing the cost.

COST OF 1,500,000 CAPACITY WITH DIFFERENT DIMENSIONS.

Gallons.	Diam.	Depth.	Cost.
1,500,000	112	20.5	$37,600
1,500,000	115.5	19	17,550
1,500,000	118	18.5	17,600
1,500,000	150	11.5	19,900

SECTIONAL RESERVOIR COVERING.

On account of the cost of centering for the type of vaulting described in this paper, it has seemed to the writer that it would be desirable if some form of vaulting could be devised in which this

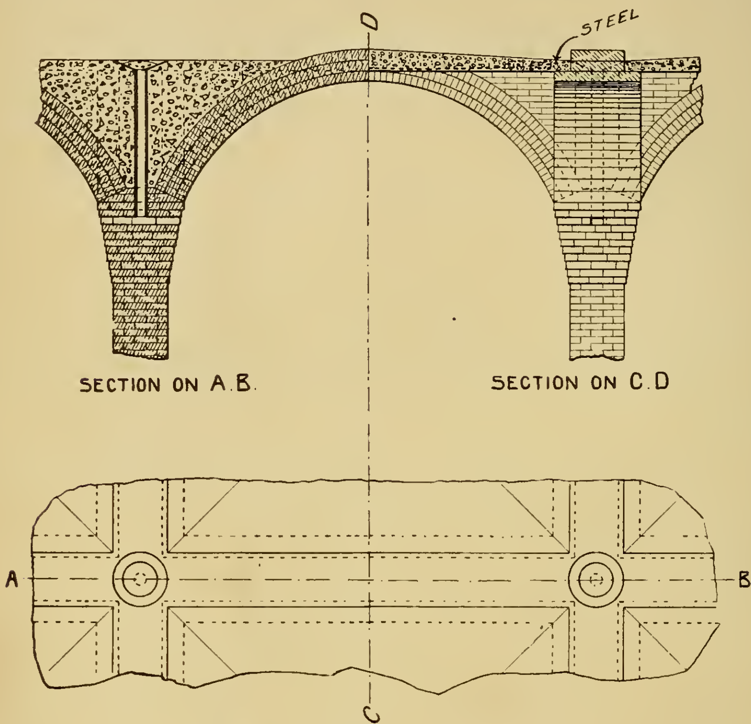
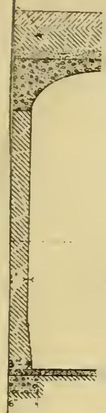
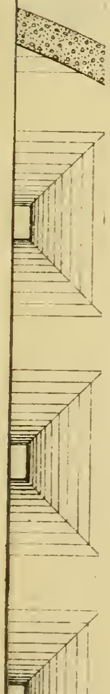


FIG. 9.

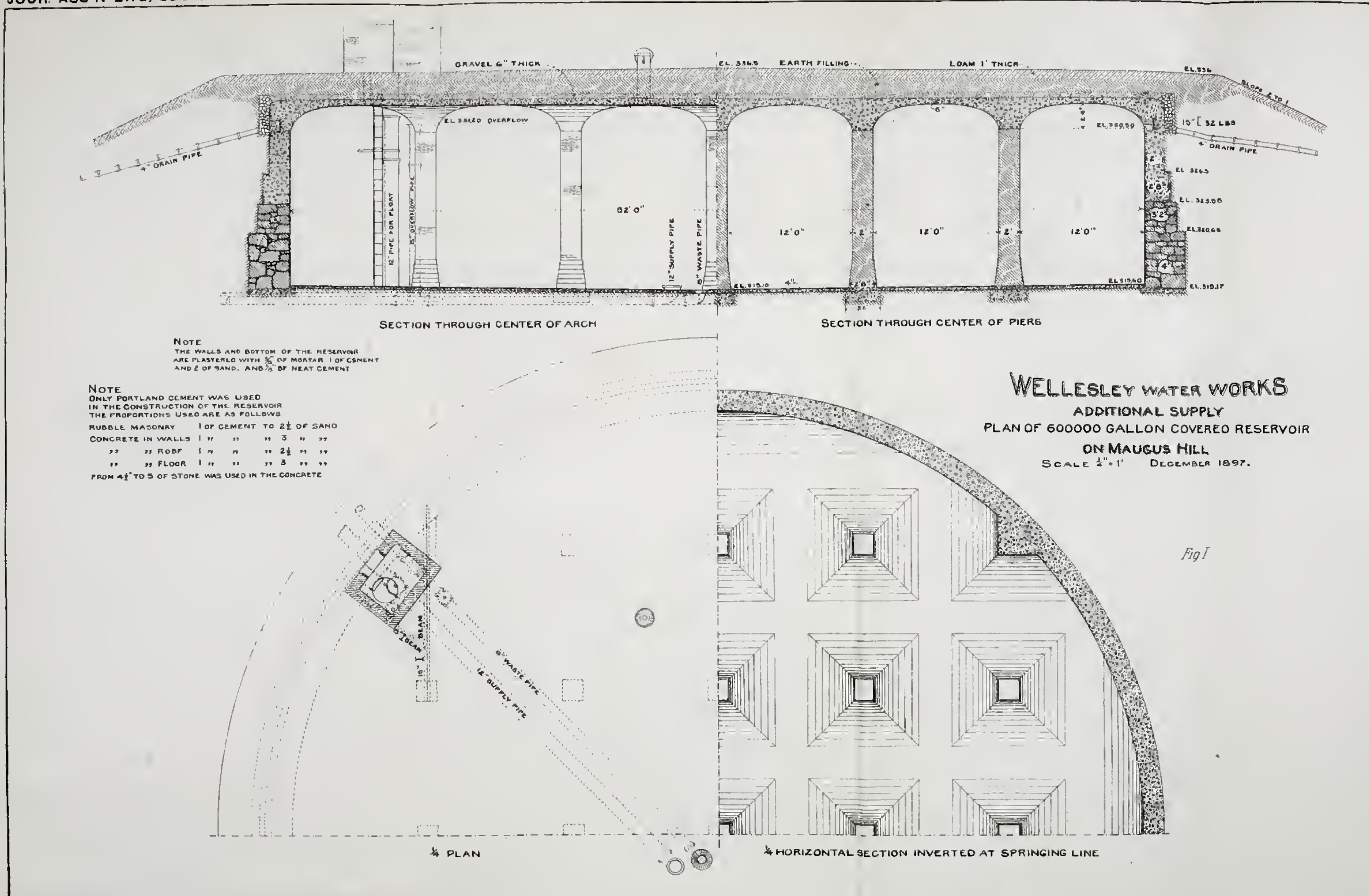
cost can be reduced and the advantages of the groined arches retained. The very successful use of a combination of steel and concrete in floors that sustain heavy loads has suggested the adoption of some such type of construction for covering reservoirs. It is undesirable to use in this work steel that cannot be thoroughly imbedded in concrete. For this reason, and because they will cost more than masonry, it is not proposed to support the covering on steel girders, as the floors are supported. It is proposed to build brick piers spaced the same as for the groined arches, and from

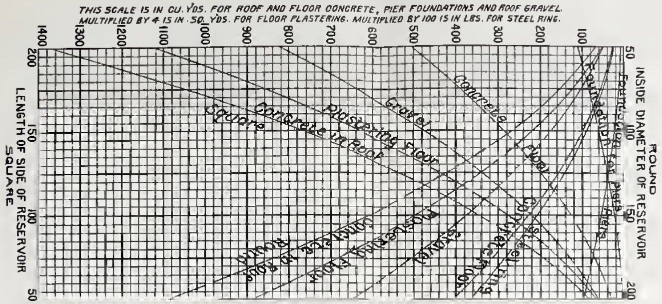


N THROU



ECTION I

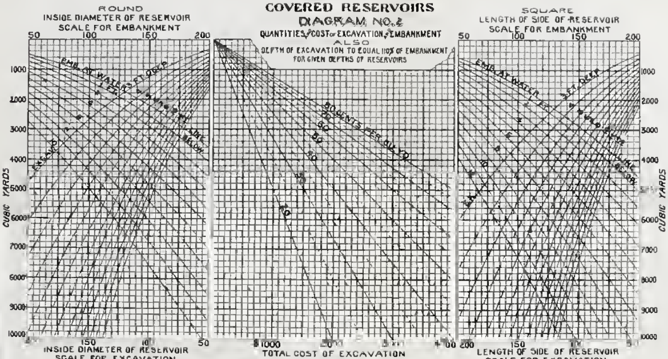

GRAVEL 6" THICK
EARTH FILLING
LOAM 1' THICK
EL. 336.5
EL. 336
SLOPE 2 TO 1
4" DRAIN PIPE
4" DRAIN PIPE
EL. 333.00 OVERFLOW
12" PIPE FOR FLOAT
8" OVERFLOW PIPE
82' 0"
12" SUPPLY PIPE
8" WASTE PIPE
12' 0"
12' 0"
12' 0"
2'
2'
15" [32 LBS
EL. 326.5
EL. 323.50
EL. 320.65
EL. 319.60
EL. 319.17
EL. 319.10
SECTION THROUGH CENTER OF ARCH
SECTION THROUGH CENTER OF PIERS
NOTE
THE WALLS AND BOTTOM OF THE RESERVOIR ARE PLASTERED WITH 3/8" OF MORTAR 1 OF CEMENT AND 2 OF SAND, AND 1/8" OF NEAT CEMENT
NOTE
ONLY PORTLAND CEMENT WAS USED IN THE CONSTRUCTION OF THE RESERVOIR THE PROPORTIONS USED ARE AS FOLLOWS
RUBBLE MASONRY 1 OF CEMENT TO 2½ OF SAND
CONCRETE IN WALLS 1 " " 3 " "
" " ROOF 1 " " " 2½ " "
" " FLOOR 1 " " " 3 " "
FROM 4½ TO 5 OF STONE WAS USED IN THE CONCRETE
WELLESLEY WATER WORKS
ADDITIONAL SUPPLY
PLAN OF 600000 GALLON COVERED RESERVOIR
ON MAUGUS HILL
SCALE 1/8"=1' DECEMBER 1897.
Fig I
8" WASTE PIPE
12" SUPPLY PIPE
10" I BEAM
¼ PLAN
¼ HORIZONTAL SECTION INVERTED AT SPRINGING LINE



NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIRS
" " " BOTTOM " SQUARE "

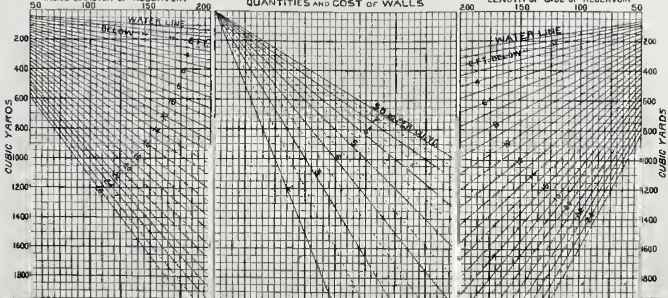
COVERED RESERVOIRS
DIAGRAM NO. 1

COVERED RESERVOIRS
DIAGRAM NO. 2
QUANTITIES, COST OF EXCAVATION, EMBANKMENT
ALSO
DEPTH OF EXCAVATION TO EQUAL 110% OF EMBANKMENT FOR GIVEN DEPTHS OF RESERVOIRS

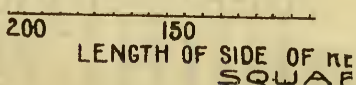


NOTE: Quantities of Embankment contain 10% added for Shrinkage

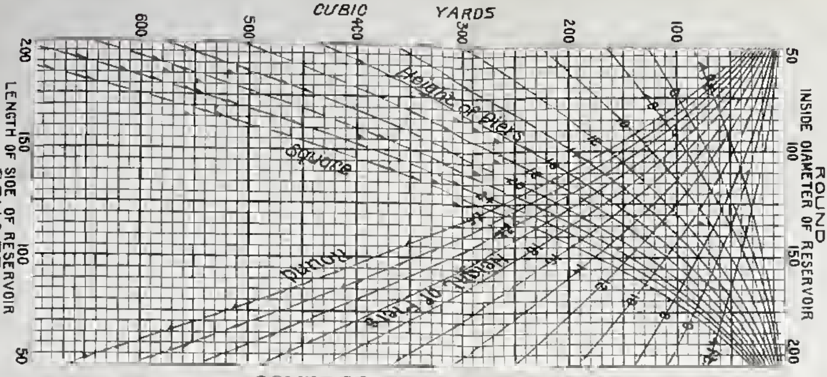
COVERED RESERVOIRS
DIAGRAM NO. 3
QUANTITIES AND COST OF WALLS



JOUR.

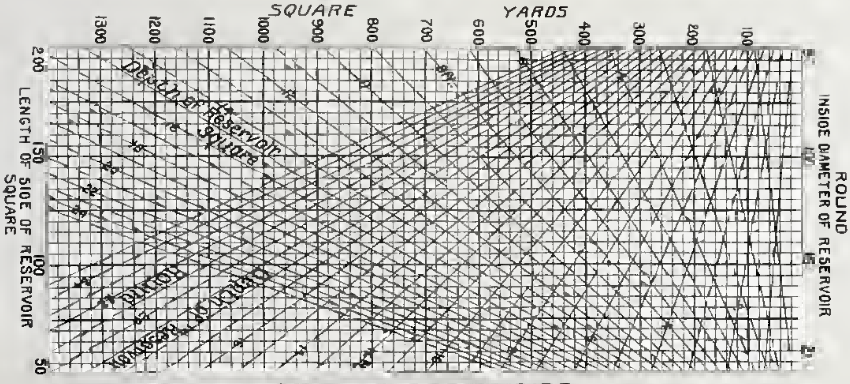


21



NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIRS
" " " BOTTOM " SQUARE "

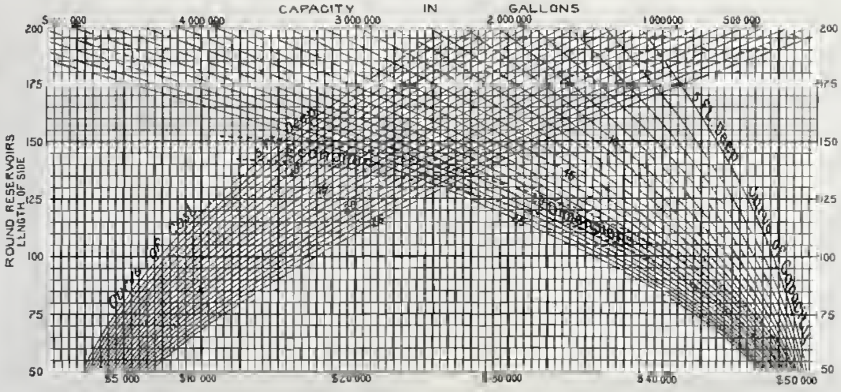
COVERED RESERVOIRS
DIAGRAM NO. 4
BRICK PIERS



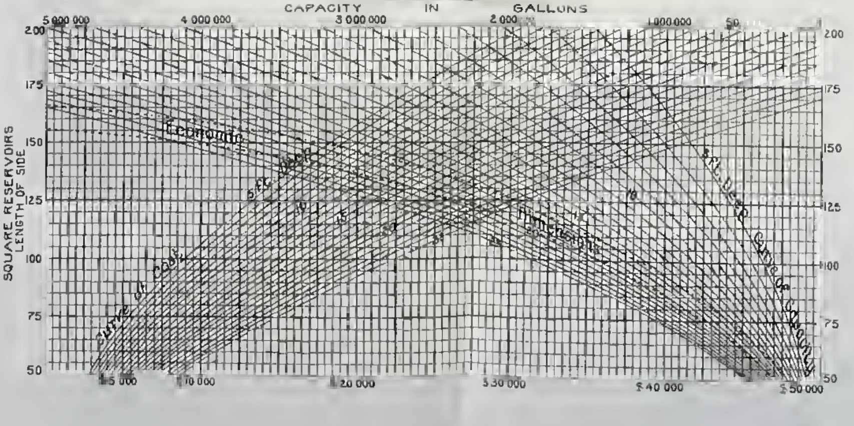
NOTE:
SEE SCALE AT TOP FOR ROUND RESERVOIR
" " " BOTTOM " SQUARE "

COVERED RESERVOIRS
DIAGRAM NO. 5
PLASTERING INSIDE FACE OF WALLS

COVERED RESERVOIRS
DIAGRAM NO. 6
COST AND CAPACITY



COVERED RESERVOIRS
DIAGRAM NO. 7
COST AND CAPACITY



these piers spring brick arches each way, as shown in Fig. 9. These arches will support a slab of the steel-concrete, as shown in the figure.

The advantages to be secured in the construction of this type are that simple circular centers can be used for the brick cross-arches, and only enough of them will be necessary at one time to build one line across the reservoir, as there is no diagonal thrust caused by the arches. The centers, or rather forms for the covering slab, will be simply a plain flat surface; as many or as few of them may be prepared as may be required for the proper rate of prosecution of the work. The best of work can be secured in the slabs, as they are made independently of each other and can be finished before the concrete is set; therefore with a perfect bond throughout.

This type of covering will give practically the same head room and arrangement for ventilation as the groined arches, and will, I believe, be cheaper and less troublesome to build. The thickness shown in Fig. 9 is not to be assumed as correct. No computation has yet been made to ascertain this correctly. One of the companies that supply the metal for this construction, in answer to an inquiry, stated that it was probable that under the named conditions No. 4 gauge metal and 6 inches of concrete would carry 300 pounds per square foot, but advised the writer to make the computations himself. He had already found that the distinguished mathematician St. Venant has said that the problem of the strength of a square slab supported at its four edges is incapable of solution, and has therefore not yet made the computation. Experiment is the proper method of determining the safe thickness, and fortunately, if it should be desirable to build this form, such experiments on full-size test pieces in place could be readily made. Lacking such knowledge, it has not seemed advisable to make any estimates of the cost for comparison with that of other types.

FIELD NOTES OF A CIVIL ENGINEER.—DO THEY BELONG TO HIS CLIENT OR TO HIMSELF?

By J. Vander Hoek.

[Read at the regular monthly meeting of the Engineers' Society of Western New York, Buffalo, N. Y., October 7, 1895.]

Mr. Chairman and Gentlemen: When I was asked by a member of the Topic Committee of this Society to prepare a paper on the question, whether the field notes of a civil engineer belong to his client or to himself, I had never given this matter any serious consideration. During the few years of my practical experience in civil engineering in this country I have never been placed in a position where it appeared to me that the private ownership of the field notes which I took could be of any benefit to me. For this reason I am not able to speak on this subject with the fuller knowledge of one who has often been interested in this question and whose opinion has been matured by the discussion of the various features of cases which have presented themselves to him in practical life. I have, nevertheless, accepted the invitation and prepared this paper, because I consider the topic well worthy of attention, and also because it appears to me that this question may perhaps be introduced with more freedom by a member who has been placed thus far outside the general engineering practice and who is not concerned, except in a general way, in the conclusion of the argument.

It will not surprise you, after receiving this communication, that I have been obliged to build up an opinion by considerations of a theoretical rather than of a practical nature, and that I have made use of actual and fancied cases only to make clear and to test the correctness of the rulings.

Before entering upon this part, I wish first to say something to define the word "field notes." Field notes may be said to refer to all data that are taken in the field, for the purpose of describing the conditions of the field, or of describing the location of objects on the field. These data are noted down in books on the ground and form what are commonly called "the original field notes." Copies of these original field notes are sometimes prepared and known as "copies of field notes." I intend to use these names in this paper to distinguish their limited meaning from the more comprehensive sense of the word "field notes," which includes also the information contained in these notes,—that is, the knowledge of which the notes are the memoranda. While the original field

notes and copied field notes refer to books, the word "field notes," in its fullest sense, stands for the information itself and has an abstract meaning.

I have made this distinction to show that while the original field notes, being tangible objects, can as such be the subject of a dispute of ownership in law, the information which they contain is something too subtle to admit of the enforcement of court decisions. For so far as the question refers to the note books, we should go to the common law for advice, and so far it forms more properly a topic in a lawyers' debating club than in an engineers' society. But if we consider it with the word "field notes" taken in its broader meaning, the issue cannot any more be decided in the courts, and may best be discussed by members of our profession. I wish here to call attention to the fact that inasmuch as the field notes are nothing else than the memoranda of certain information, it must follow that the party who is found to be entitled to the ownership of this information is also entitled to the possession of the notes.

In formulating the question, the word "client" has been used, although this word, properly speaking, refers only to a person who applies to a lawyer for legal advice. I suppose that the word client has been preferred to the word employer in order to bar from the discussion all such cases where the engineer is in the position of a regular employe. Allow me, however, to consider also such cases, because I think that there are many engagements which place the engineer, although conducting a general practice, into a position similar to that of an employe. Moreover, the relation between the employer and the employe is a very simple one, and the features thereof are well understood, so that a study of the question under the conditions of this class affords the opportunity to point out some fundamental principles.

I have found it most expedient to divide the cases of various relationship which may exist between civil engineers and their employers and clients into two classes, and to consider the question under the different conditions of each class separately. The particular feature of the first class is that the engineer is paid for all he does, while in the cases of the second class the engineer is not paid for his work, but for the product or result of his work. In the first class he is paid by time, in the second by piece.

I wish now to consider our question under the conditions of the first class; two typical cases have suggested themselves to me, namely:

(1.) The engineer is a regular employe and receives a salary.

(2.) The engineer has a general practice and charges by time.

Referring to the engineer as an employe, I would say that he agrees to work steadily and exclusively for his employer, and to devote all his time to his employer's interest. He cannot properly work for another party without the consent of his employer. He receives in compensation a regular salary, which he accepts in full payment of all services rendered during the period of time for which the salary is paid. Considering our question under these circumstances, I would say that the common law governing the ownership of the products of labor, performed by employes on the time of their employer, does not leave room for any difference of opinion as to whom the original field notes belong. I do not think that there can be any dispute of this point, as whatever the employe produces in the time of the employer is the property of the employer. As to the right of employes to copy the notes in their own time for their own benefit, I would say that they have no such right, because the employer has not only paid for the work of writing down the notes, but for the work of obtaining the information, and, therefore, this information itself properly belongs to the employer as well as the notes.

However, the engineer does, as a matter of course, gain more or less information while he is engaged in gathering the field notes, whether he wishes or not; and while the employer may refuse his employe the privilege of preparing copies of the notes, which he has taken, for private use, he can certainly not take away from him the knowledge which he has acquired. The question now comes up whether an engineer working under such conditions has a right to make notes from memory for private use.

I take leave to give in this connection a few lines taken from the issue of *Engineering News*, dated March 22, 1894:

"In a late issue of the *Troy Polytechnic* Prof. W. S. Raymond answers another writer in the same journal, who, in the course of a paper, noted that a certain civil engineer discharged his best assistant for keeping a private note book. This engineer explained his action on the ground that these notes of survey were the private property of the chief; that they were valuable to him as a guide in making future surveys, and hence were decreased in value by duplication. Mr. Raymond suggests the desirability of presenting another side of the question, which, he believes, is more correct in principle, as follows:

"Mr. Raymond believes the young assistant is entirely justified in recalling at night the work of the day and in making notes of it.

He does not use his employer's time in field or office, and as he gains in experience he becomes more valuable to his employer. In fact, a part of his salary is this experience, which is practically the knowledge he gains of certain methods and of the locality in which he works. If he uses his employer's time, however, in making his notes, he is obviously doing wrong, though he is following an example constantly before him."

Allow me to say that in my opinion the side presented by Mr. Raymond is not correct in principle. Although I gladly concede the right of every man to prepare memoranda of his day's work and of whatever appears of interest to him, I do not think that he can consider the information so collected as his private property. He should never lose sight of the fact that these memoranda were made while he was in a position of confidence, and that he gathered the data while in the discharge of his professional duties. Information obtained under such circumstances should not be used without having due regards for the interest of the party who paid for the work. From a practical standpoint no one can dispute that this information belongs to him, but from a moral standpoint I would say that it is not owned, but, so to say, held in trust, by him.

I wish to give one example in support of what I have said and to select a strong one in order to present the points at issue as clearly as possible.

Suppose a railroad company employs a civil engineer for the purpose of finding a route through a very difficult piece of country and spends large sums of money in extensive surveying in order to secure the very best location, or perhaps the only feasible one. A second railroad company, as is not unfrequently the case in this country, desires to construct a line through the same territory, but has no surveyors in the field. Under such circumstances the information gathered by this engineer is not only very valuable to the first railroad company, but equally valuable to the second one. The company who pays will therefore not only exercise its right to the original field notes, but has good reason for refusing the duplicating of the notes. It can, however, only protect itself for so far as the actual notes are concerned. The engineer of the party acquires after many surveys more or less complete knowledge of the country examined, and can, without referring to note books, point out to the second company the best or only feasible location. Can he now consider this knowledge as his private property? If so, he should have a right to do with it as he pleases. I do not know whether the common law would stand in the way if this

engineer saw fit to offer his information for sale to the rival company, but all honest men will agree that in so disposing of his private notes he would place himself on one line with a common cheat. In this case we find that the engineer has no right to dispose of this information, and for that reason it cannot be said to be his property.

I will admit that in the general run of engineering work the information collected during its consummation is not of much benefit, except to the party who paid for it, and that, therefore, the exclusive possession of it is not considered of importance. Neither do I think it necessary for an employer to prohibit his engineer to take copies of notes, except in special cases; but where there is here a question of right to be answered, I would say that the importance of the possible consequences does not alter the principle involved.

The knowledge that comes to the engineer while doing work for others becomes part of him in the same way as a lawyer becomes acquainted with the legal situation of his client, and as the physician learns the physical infirmities of his patients. Neither of them actually own this knowledge, and they are at liberty to make use of the notes for such purposes only as are in the interest of the client and the patient, or in the general interest of their profession.

The large body of subordinate engineers who are employed as assistants to chief engineers come under this class, and I suppose that we all agree that a civil engineer, placed in such a position, should be faithful and loyal to his superior, and that the chief has a right to expect that his assistant shall treat as confidential all important information that may come to him in the performance of his duties. That, as a matter of fact, many employes do consider information obtained during the work as their property is, I suppose, due to a large extent to the neglect of their employer to exercise his right. Sometimes the employe is allowed to consider himself as the sole owner of the field notes by the lack of interest taken by his employer, and this accounts for the strange notions which are found in the heads of some employes.

I wish to cite here again from *Engineering News* for an illustration:

"As a case in point, though not exactly connected with the class of employes here dealt with, the editor is reminded of a bit of experience of a one-time chief of the water department of one of our largest cities.

"This chief succeeded to an office practically devoid of all

records of work performed, and he was forced to have complete re-surveys made of the much scattered property, buildings, reservoirs, etc., under his control. The engineer charged with surveying the reservoir finished the work above ground with little difficulty, but there was a chain of reservoirs connected by a very complicated system of buried pipes and gates, and it was absolutely necessary for the completeness of the work that this connecting system should be accurately mapped. But here he met an obstacle in the form of reservoir keepers, who had held their offices throughout all changing administrations simply because they, and they alone, knew where the pipes, gates and stops were located, and how they were connected with the city system. These keepers positively refused to give away this private information, and there was a halt in the survey. The chief, however, was equal to the emergency, and, sending for the keeper of one of the smallest reservoirs, he personally requested that he point out to his engineers all this underground plant. The keeper again refused to comply, and, somewhat to his surprise, he was discharged upon the spot. The next morning a gang of laborers appeared at the reservoir, formerly in charge of this keeper, and a trench was cut clear around it; every pipe was uncovered and followed to its connection or stop, and a complete survey was then made and mapped. It is hardly necessary to state that there was a sudden change of heart among the other keepers, and the engineer in charge of surveys had little further trouble in getting all the information he needed."

It seems to me that the blame in this example rests more with the engineers who constructed the water works than with the gate keepers; and it has been given for the purpose of showing with what undesirable results the employer might be confronted if he should have to depend upon employes who consider as private property the knowledge which they gain in the discharge of their duties.

I now wish to consider other cases of this same class, but of the second type, which refers to engineers who are not in the position of an employe, but are conducting a general practice. They render services and do work for various parties who call upon them for that purpose, and charge their employers or clients fees, dependent upon the amount of labor involved, or on the importance of the services rendered. Although there may exist an understanding as to the amount of the fee, per day or per hour of labor, there is no agreement as to the amount of the final bill. In other words, the engineer, to use a contractor's expression, charges for the work by force account. I would say that although the very

highest kind of engineering services belong to this group, from a legal standpoint the conditions existing here are very much the same as those under which a regular employe is engaged. It is true the engineer is not expected to devote all his time to the work of this one client; a man in general practice is understood to divide his attention between several matters. But the important point which, I think, rules here is that the agreement provides that the client shall pay for all the time and labor involved and, for that reason, is entitled to all the results of the work. The engineer employed in this manner is only in so far differently situated from a regular employe that he is in a larger measure independent, but this does not confer any more rights to the results of his work than a permanent employe has.

I can readily see that in actual life the engineer keeps the field notes, guided by the idea that they are more valuable to him than to the client, and also because he feels that he will take better care of them than the client himself. Moreover, the field notes of one piece of work may be very helpful in the study of another one in the same neighborhood, and in this way do increased service. But these considerations are all based on convenience, and do not establish any owner's rights. If the client does not claim the field notes, all is good and well, but in case he insists upon having them, I think that justice and the law are on his side.

Suppose, for instance, that the engineer, who has entered into an engagement of this type, should die while the work is in progress, and that already a large amount of field notes have been collected, the possession of which is necessary for carrying on the work. I do not doubt but that we all agree that, under such circumstances, the client should have the right to take possession of the notes upon payment of their cost. Yet the death of the engineer does not in any way diminish his rights, and if the notes properly belonged to him while alive they could not have been claimed by the client after his death.

There are a good many other cases where the field notes are very valuable to the client. I give below a few instances which cover the most important conditions:

Whenever an engineer is called upon to make a survey for a map which is to be on a small scale, as, for instance, a topographical map of a section of the country, he is unable to make his map show all the details as clearly and precisely as the field notes will afford. Generally speaking, the precision of a survey should not be any greater than required for the accurate mapping to a given scale, but in many cases it is more convenient to measure the

topography with greater precision than can be represented on the map.

The field notes have, on account of this additional information, considerable value. Besides, the notes are absolutely necessary when the time comes for making alterations to and corrections on the map. It seems evident that the client who pays the engineer for making such a map should receive all the field notes with the map.

I wish also to call your attention to surveys of lines and objects which are subject to changes by natural forces and where it may be important to use the field notes for precise relocation of objects afterwards.

For instance, in all cases where improvements are proposed which may interfere with the flow of water in rivers and streams, or change the stage of water, etc., a complete set of field notes is very important to the client, because in after times some one may come to the front with a claim for damages alleged to have been caused by the works. The original field notes will then give evidence as to the situation before the improvements were carried out.

A very common case where field notes are of the greatest importance to the client is when they refer to contract work and are to be used for calculating the quantities which are to form the basis of settlement between the contractor and the client.

Last, not least, I would call attention to those cases where an engineer has charge of the engineering in relation to municipal improvements, which require for their maintenance a full knowledge of their construction. I wish here to refer especially to sewerage systems, water works plants, laying out and grading of streets. Although from a legal standpoint it seems to need no argument that an engineer engaged upon such work and charging his client for all the work that he has done has no right to the field notes, yet it is not a difficult matter to cite cases where the engineer has claimed all the notes as his own.

I will cite here one case given in an editorial of *Engineering News*, dated July 14, 1892, in the form of an answer received from a city engineer in response to a request for information regarding the sewerage system of a city with more than 30,000 inhabitants, which is as follows:

"I am unable at present to fill up the blank you sent me. I have been in this office only one year, and my predecessor has been here twenty-six years. When he left he claimed the few records he had kept as his own, and he left me very little more than the bare

walls of the office. He has a book containing the record of sewers now in use, which he offered to sell to the city, but the Council refused to buy, as they feel it should belong to the city by right. I think they will soon decide that the cheapest way to get it will be to buy it, and I will then let you know what it contains. As there were no records or notes of any kind in the office, except a record of street grades, I have not been able to make much headway during the year. I hope to get affairs in shape soon so that the records from this office can take their place with those of any other well-conducted office."

It is apparent that the law does not make itself felt strong enough to impress everybody with the necessity to keep on the right side of it. I have not been able to find any legal decisions directly bearing on this question. This, I think, is more due to the fact that most clients have no adequate idea of the importance of the notes, and consequently do not care about them when it is the proper time to ask for them, than because there is no law to sustain their rights. However this may be, there is in addition to the written law of the land an unwritten one of honor, of which no engineer can afford to disregard the precepts if he desires to practice successfully in his profession. The relation of the engineer to his client, especially where the engineer is invested with the authority to use his own judgment as to the amount of work necessary for the successful completion of the work on hand and where he charges accordingly, he occupies a position of great confidence and responsibility, and he cannot be said to serve his clients well if he does not supply them with all the data and information that may have to be referred to afterwards for the operation or in the maintenance of the completed work. The engineer should assume somewhat the same relation to the client as an attorney, and take full charge of the client's interests as if they were his own, and if the client is not able to appreciate whether the services rendered are more or less complete, the engineer should feel an increased necessity of protecting his client and not take advantage of his inexperience.

It is proper in this connection to quote from the address which Mr. S. Whinery, M. Am. Soc. C. E., former President of the Cincinnati Engineers' Club, delivered at the annual meeting of December 15, 1892.

Speaking of the engineer's duty to his client relative to chief engineers reporting directly to corporations or those engineers who have a general engineering practice and who charge their clients fees dependent upon the labor involved or the importance of the services rendered, Mr. Whinery says:

"When an engineer undertakes to do certain professional work for a client or employer, it is obviously his duty to devote himself to the interests of that client with conscientious zeal and fidelity. His personal interests or affairs cannot be allowed to stand in the way of loyal devotion to the interests of his client. The only exception to this rule is where the demands or the interests of the client conflict with the engineer's sense of right and wrong."

Basing himself on this principle, Mr. Whinery gives the following answer to this question: To what extent do the facts acquired and the results reached in professional work belong to the client for whom the work is done and to what extent do they become the property of, or can they be made use of by, the engineer? The answer is:

"It would seem clear without argument that all the original notes, maps or plans and information, as well as the final result or report, are the property of the client, who pays for having the work done, unless there is a previous understanding to the contrary. There is, however, no reason why the engineer should not retain copies of such documents as a part of his stock of knowledge and engineering equipment for other work. The information thus collected and preserved may be of great assistance to him in future engagements, and it may sometimes become important as a means of defending his personal character. The privilege of using information acquired in the services of a client is subject to one condition that no honorable engineer will violate. Such records and facts cannot be used to oppose in any way the business interests of the client for whom the original work was done."

I would say that this answer deals fairly with the question at issue, because it secures for the client and also for the engineer the largest measure of benefit without harm to any one. It is reasonable and just that the engineer should retain copies of notes for his own protection in case afterwards the quality of his work should be called in question. A good example of such a case was furnished by Mr. Cummings in the meeting of the Montana Society of Civil Engineers in the month of April, 1894:

"An engineer in that State is often called upon to run some important connection lines in the mines, and the execution of the work after it is laid out devolves upon the mine superintendent or foreman. If he should fail to follow the engineer's lines and instructions the work when completed might not connect, and the engineer would be liable for an action for damages. If he had parted with his original notes he would have nothing to show that his work had been correctly done and where the fault really lays."

I take leave to say here that in the same meeting the opinion of those present was that the employer was entitled to all the notes and information obtained from any survey, but that the engineer making the notes ought to have the right to retain either the original notes or a copy of the same whenever he considered them of importance for future use, provided they were not used to the detriment of his employer's interest.

Let us now leave off the discussion of our question as related to time work and enter upon the study of cases of the second class, where the engineer is doing piece work. The characteristic feature of the relation between the engineer and his client under these circumstances is that a certain amount of work is to be performed, the compensation for which is not to be measured by the time involved nor the necessary labor, but solely by the results obtained. Generally speaking, the parties enter into a contract by which the client agrees to pay a certain sum, in consideration of which the engineer agrees to produce certain results.

Referring to these cases, I would say that from a legal point of view there can be no other obligation on the part of the engineer than to comply with the terms of the contract. I do not think that under the circumstances the client can have a legal right to anything else than what he has contracted for. The understanding is involved that the engineer is not going to be paid for his time, and is to have no claim upon the client for compensation until these results have been delivered. A part performance of the contract does not entitle him to a proportionate part of the compensation, and he can recover nothing until all the work is done. Only when the failure to complete the work or perform the contract in full is not the fault of the party who has agreed to do it, or if he has been wrongfully prevented by the other party from completing the work, is he entitled for what he has done. On the other side, if the engineer fails to perform his part of the contract he cannot be compelled to perform the contract against his will, but only damages can be recovered for his refusal unless there be no adequate remedy at law in money or damages. If, therefore, the contract calls for a map, a plan or a report, which is to be prepared by the engineer, the client has no right to anything besides this map, plan or report. The engineer is not paid for his labor, but for the map, plan or report, and whatever additional fruits his labor may have had belong to himself. For this reason I think that the original field notes belong to the engineer, unless the contract provides otherwise.

It is probably on account of such considerations that many contracts entered into between corporations or parties, who desire to

possess the field notes, contain a special provision to that effect. The contract between the village of Batavia and the engineer who has charge of the execution of a sewerage plan for that corporation provides that the field notes shall be turned over to the village authorities.

I understand that the contract relative to the re-surveying of property lines between the city of Rochester and the engineer stipulates that he is to furnish the city with a correct copy of all field notes.

Another example of which I know is in connection with the sewerage work of the village of Charlotte. Also there the field notes were to be the property of the village. I do not know of any contracts where objections were made to the preparing and keeping of copies of the notes. In other specifications for engineering work no special reference is made to the ownership of the notes, but the plans and maps are required to show practically all the information that is contained in the field notes. It appears to me that, wherever this is practicable, this is a very desirable way of getting the benefit of the notes, because the data in such form are at once indexed and ready for reference in the most convenient manner.

Having concluded above that the original field notes belong to the engineer where the engineer is paid for results, I beg leave to add here that this ruling does not end the matter. The question only takes another form, and now presents itself as follows: to what extent should the engineer impart the information of the field notes to his client? It is, as a matter of course, a difficult one to answer, except in a general way, as every piece of work has its special requirements. It would certainly seem advisable wherever engineering work is given out by the piece that a definite understanding be first reached between the parties, so that no room be left for personal interpretations.

There occur in actual life, however, a number of cases where the whole question is carelessly left to the discretion of the engineer, and I am sorry to be obliged to say that there are many instances on record where the engineer purposely kept to himself the information which was necessary to render his work complete, in order thereby to secure additional employment. Allow me to cite a letter, which appeared in the number of *Engineering News* of April 19, 1894, on this subject:

"I am at present engaged on a piece of work where the lack of notes is particularly aggravated. The engineers who make the land surveys in a certain town but a few miles from New York charge by the lump sum for each piece of work. Recently some

differences of opinion arose between the authorities and some property owners regarding a certain street, of which the grading had just been completed. I was engaged by one of the property owners to investigate the question, and on applying at the proper offices was informed that all notes, cross-sections and detail material were the private property of the engineers and could not be seen. Nothing was on file but the profile of the center line of the street in question, and that gave exceedingly meager information. It was not until legal proceedings were suggested that the engineers consented to allow a copy of the notes to be made.

"The same men are not only the engineers for the town spoken of, but also for a city of considerable size. As I happen to live in the town, these things became a matter of considerable interest, and upon investigation I find that, though the entire town has been monumented at public expense and mapped, there is nothing on record showing that there are any monuments, let alone giving their location or references. Much work has been done of which there are not even plans, though ample fees have been paid for the work to cover the most complete records.

"The entire engineering records are in the same shape. The excuse is now offered that 'it has not been the custom of engineers to file the notes or other data,' neither does it seem to have been their custom to file complete plans or maps.

"In this case the sole object sought for seems to be to impress the authorities more with the appearance of the maps and profiles than with their value, as the lettering is very well done and quite conspicuous, and from appearances it would seem that more time has been spent on the titles than on the rest of the work. While neat work is always creditable and always to be desired, fancy lettering at the expense of valuable data is a waste.

"It seems to me that if your paper would continue to agitate the question, and if reputable engineers would take up the matter in earnest, much good might be accomplished. Engineers who are guilty of such practices, it seems to me, should be shunned by their fellow-members of the profession. I would suggest that some good could be accomplished by making such practices a cause of expulsion from membership in the various engineering societies throughout the country."

Although I do not wish to take up the war cry of the author of this letter, I am bound to admit that the principle for which he stands is correct, and I would consider this paper incomplete if no reference was made to the undesirable effects which the practice of reserving notes of land surveys as private, exclusive property

of the engineer has had upon the preservation of important property lines. The purpose of the offices of the County Clerks, established for the recording of all information relative to land properties, has to some extent been defeated by the meaningless descriptions and plats which are found in the files, and which render the work of locating some property lines equal to the solving of a Chinese puzzle.

The engineering profession cannot free itself of all blame in allowing this state of affairs to exist, because, although it has not the power to place the surveys of this country on a firmer basis, it must be admitted that the practices of some surveyors, to keep the field notes of surveys carefully to themselves and to furnish maps and descriptions with the least possible information thereon, has largely increased the difficulty of relocating important property lines. I would add that this practice cannot be considered as in the interest of the engineering profession, and must have the tendency of lowering its standard among other professions and in the community at large. I have seen this summer in the hands of attorneys, representing neighboring property owners, plats prepared by professional surveyors showing the location of the dividing line between these properties thirty feet apart. They are located in the dock section of this city, and where land is very valuable. Several months have passed since, and, so far as I know, no location has as yet been made, so that it will be necessary to compromise. Is it a wonder that the public has no high estimation of the surveying business? Such a condition of affairs could not have come about if each engineer had done his work faithfully and fully, and is largely due to the practice of furnishing plats and descriptions of land without the necessary information for re-establishing the boundary lines. I would say that although the contract may not require him to turn over the field notes to his client, yet the engineer is under the obligation to complete his work, and any map or plat which does not contain sufficient data to enable any surveyor to relocate the property and to ascertain its location with reference to abutting properties cannot be said to be complete. This question has been fully discussed in the editorial of *Engineering News* of March 29 of last year, from which I beg leave to copy:

Mr. Raymond says that the question of what constitutes a survey arises at once in this discussion, and the answer must depend upon the object of the survey. Surveys for subdivisions of large tracts, or surveys intended for establishing the boundaries of a known tract, or for determining a description when the boundaries are known, are alone considered here. The principle enunciated applies, however, to any survey.

"A survey is the operation of finding the contour, dimensions, position or other particulars of any part of the earth's surface, and representing the same on paper. The setting of corners, or monuments, and their description becomes a part of the survey, and the maps, together with the notes, should show faithfully the ground, the work done and the items mentioned. The purpose of establishing corners or monuments is to mark on the ground the boundaries of tracts, to plainly define the location with reference to other tracts and to enable future surveyors to correctly trace the boundaries. The survey is evidently not complete until the corners are fixed, proper information obtained and the same put into the maps and into the notes.

"The doing of all this constitutes a survey, and the question now is to whom does this survey belong? Mr. Raymond believes it belongs to the individual who pays for it, and it is hard to see how these surveys, or any part of them, can become the sole property of the surveyor. The latter may keep notes to facilitate his future work, but he cannot properly claim a single note made in the time paid for by his employer.

"If, however, the surveyor takes the work not on time, but for a definite sum for the entire job, he may take as much time and as many private notes as he likes. But, as he is bound in honor to return to his employers the survey complete in every detail, it is not obvious that his private notes would be of great assistance to him in securing further work, especially when it is remembered that professional men of repute do not bid against each other for such work. His reputation for accuracy and honesty will be worth much more than any quantity of private notes.

"The records of monuments and street lines made by a city engineer are no more his private property than are the records of the city clerk, auditor or treasurer. Court decisions indicate the correctness of the position here taken, though much laxity is shown in this respect by city engineers and county surveyors. The method of regulating the pay of these offices has doubtless much to do with the practice. Where the surveyor receives no salary, but is allowed to collect certain fees for work performed, there is some color to the claim that his work is private work and belongs to him. That this is not true concerning the public work done by these surveyors and engineers is believed to be evident from what has proceeded."

The editorial article goes on with laying down a set of rules to which each property map should conform, and further suggests the enactment of laws to force compliance, but I prefer here to finish this paper.

I have observed with pleasure that gradually many landowners in the suburbs of this city are placing permanent monuments at important corners, and if this practice is extended the value of private field notes will surely lessen.

If I am correctly informed, the practice of considering notes of surveys, relative to other people's land, as private property has grown out of the undeveloped conditions of this country in years gone by, when the engineer's private office was the only depository of such records. I have no doubt that in the course of time the importance of public records will be more and more realized, and with their growth and development will come an end to "private field notes" as a factor in the engineering profession, in which they should have no place.

MECHANICAL DRAFT.

By Henry B. Prather.

[Read at the regular monthly meeting of the Engineers' Society of Western New York, Buffalo, N. Y., July 1, 1895.]

Probably no subject is of more importance to-day to the engineer and to the manufacturing and steam using world than that of the economical combustion of fuel in the furnace of the steam boiler. That even with the best arrangements of modern steam plants for the conversion of calorific into mechanical energy but a small efficiency is obtained is a well-established fact, and yet possibly more startling than some realize. Theoretically each horse power should require about 0.212 pounds of coal per hour, and yet the very best engines and steam plants require from 1½ to 2 pounds, —*i.e.*, about ten times as much and good practice fifteen times as much and the great majority of good engines in daily use fifteen to twenty times as much,—*i.e.*, 3¼ to 4¼ pounds coal per horse power per hour and show a ratio of actual performance to the full calorific power of fuel consumed of 5 to 8 per cent. A great portion of this loss of 9-10 to 19-20 of the work represented by the fuel combustion is unavoidable, arising as it does from the physical qualities of water employed as a vehicle for the use of heat. A perfect heat engine could save but about 16.9 per cent. The best designed engine and steam plant will in fact yield but about 6 to 8 per cent., and hence the ratio of practical performance to the perfect plant under usual conditions is about 35 per cent.; in other words two-thirds of the heat work that may be striven for is lost. This loss is in the engine chiefly, and also partly in the boiler, and hence appears the vital value of improvements in combustion and boiler efficiency which will tend to reduce this two-thirds loss of possibly available work.

This subject has commanded the best efforts of our greatest steam engineers for years—men such as Chas. E. Emery, John C. Hoadley, Wm. R. Roney and others have given the subject exhaustive study and experiment—with gratifying results, it is true, but that there is still a wide field for improvement will be realized when it is understood that the relative efficiency above referred to of 6 to 8 per cent. has, with such economy facilitating devices as mechanical draft, water grates, improved furnace and boiler designs, mechanical stokers, etc., been improved upon only to the extent of 10 to 30 per cent. There are, besides the high-class modern steam plants of comparatively recent installation, a vast number of plants, large and small, on land and water, where limitations of first cost

forbade improved devices, and even many high-class boiler plants which are susceptible of great improvement in efficiency, and offer a large field for apparatus tending to such and obtainable at a reasonable or low cost. Examples of such plants are the many small power plants in our hotels, office buildings and factories, and on board our many passenger and freight-carrying steamers and barges. There are many applications and devices on the market which claim to have the panacea for all the evils a boiler plant is heir to; some are really of value, some are purely "quack" devices. Hence a study of this subject is of great value from a negative as well as from a positive standpoint. It is hardly less worth while to know the absolute limitations of economy in coal combustion, to know what cannot be done, to know the good and bad features of exploited devices, though quacks promise never so much, as to learn by what means some of the important loss of heat in existing arrangements may be saved and put to use at a reasonable cost and without undue trouble. It is the object of this paper, by a description of some of the most important experiments and data made and obtained in the line of boiler economy promoting devices, and especially of mechanical draft and a brief discussion of the same, to possibly present some valuable matter and at least start discussion and thought on the subject in the Society. The limitations of a single paper of this kind and the time allowed the writer for preparation of same will not permit a full consideration of the subject, and especially detailed accounts of experimental data and the many arguments pro and con on the debatable points. The importance of good draft, natural or artificial, for the supplying of sufficient oxygen for the rapid and economical combustion of fuel has long been appreciated by intelligent engineers. The gain both in efficiency and capacity obtained by the rapid and energetic combustion of the various kinds of coal and the resulting high furnace temperature is well established. Its importance has, however, been generally conceded only within a few years. The wonderful stimulus which the development of electrical industries has given to the building of compound engines has necessitated higher boiler pressures, and this in turn has greatly increased the use of water tube boilers. High initial furnace temperature is essential to the best economy with all types of boilers, and especially with the water tube type, with their large amount of heat-absorbing surface in close contact with the products of combustion, as otherwise the temperature of the gases will be lowered below the point of ignition and will pass up the chimney only partially consumed. To obtain this high furnace temperature requires proper draft to deliver

an abundant supply of oxygen to the furnace. This result is obtained by two well-known means,—viz, natural draft produced by a column of heated gases in a chimney of suitable proportions, and "forced draft," obtained by mechanically creating an air pressure under the grates with a blower or fan. A third means, less known, is mechanical exhaust or induced draft, produced by a suction fan arranged to draw the waste gases from the furnace and discharge them into a small stack. These are the various systems of mechanical draft in general use. Special features for further increasing the efficiency of the apparatus, such as utilizing otherwise wasted heat in escaping furnace gases to heat the feed water or the feed or supply air, are often added. There are numerous other devices, such as hollow "wind grates," in which the grate bars are hollow and kept full of air under pressure, but constantly escaping to feed the furnaces through small holes in the grate bars, and others. The above-mentioned, however, cover the most successful arrangements. The principal advantages urged for these various mechanical draft systems over natural draft are, first, the more effectual combustion of fuel by reason of the more abundant and intimate supply of oxygen to the furnace, using any kind of fuel; second, the obviation of the necessity for high chimneys; third, the possibility of use of a cheaper grade of coal at the same time with a proper combustion of the same, and, fourth, the almost practical abolition of the smoke nuisance by reason of the more perfect combustion of the fuel and gases.

It has been urged that the use of the more rapid draft causes early deterioration of the grates in the case of the "cold air" forced or exhaust draft by the great difference in temperature between the air supplied to the under side of grate and the incandescent fuel on the upper side; in the case of the hot draft, either forced or exhaust, by the great temperatures obtained under and on the grates causing burning or melting down of the grates. It can be shown that the first-named evil is largely exaggerated, and can be rendered slight by taking the supply of air from the boiler room and from over the boilers; as to the second criticism, which has also been exaggerated, the use of water grates,—*i.e.,* hollow grates,—with a circulation of water in them overcomes the burning out of the grate bars, even with the maximum obtainable temperatures. There is no doubt but that many of the old-time "forced draft" applications where high speed blowers deliver cold air at 2 to 3 ounces pressure under the grates, and having no economizing device for utilizing the waste gases escaping up the chimney, are not as efficient as they should be; are great consumers of power for fan propulsion and

destructive of boiler grates and shells. True, they do "make steam" quick, and when coal is shoveled in fast enough they are great "steam raisers." Of such plants a large majority have been applied on ocean steamers where limited space forbids the use of large slow-running fans and low velocity air conduits, and the principal object is fast steam-making more than economy of fuel. The value, however, of the use of even cold forced draft at pressures of $\frac{1}{2}$ to $1\frac{1}{2}$ ounces, and still more of the forced or exhaust draft with hot draft and economizer attachments in effecting an economy of from 8 to 20 per cent., is well established, and from 8 to 36 per cent. is claimed. Slow speed fans should be used whenever possible, in order to reduce the power required for fan propulsion. In this connection a brief consideration of results obtained by eminent engineers will be pertinent. From the summer of 1881 to May, 1882, at the expense of a number of the largest mill owners in New England, extended tests of "Marland's warm blast" apparatus were made under direction of the late John C. Hoadley, M. E., of Boston, at the chemical works of the Pacific Mills, at Lawrence, Mass. This apparatus consisted briefly of a "Root" positive blower exhausting the furnace gases upon leaving the furnace through a number of thin tubes about 3 inches in diameter, over which tubes the air supply for the boiler furnace was led and warmed, and thus effecting the economies of increased air supply, more effectual and complete combustion and warm feed air and its attendant results. These experiments were on a very practicable and elaborate scale, every detail being attended to and in degree of accuracy of calorimetric, anemometric and thermometric work were doubtless the most extended and valuable tests ever made of the kind. The most vital point in boiler testing, the analysis of the flue gases, was very carefully determined and elaborated, and the greatest care was taken in determining the exact power used in driving the blower or fan. The results obtained showed beyond a doubt a net saving of 10 to 18 per cent. over the best obtainable practice with natural chimney draft, and with air supply at the usual external air temperatures, at least five times as much as can be saved by any and all other methods save analogous devices (see Transactions of American Society of Mechanical Engineers, Vol. VI, pages 676-842). This apparatus has been in use several years, and no unusual deterioration of boiler, boiler grates or the warm blast apparatus itself has occurred, thus effectively demonstrating its practical efficiency. The induced or exhaust draft with feed water heating economizer as applied in many large plants consists of large slow speed fans exhausting the furnace gases over coils of feed water

heating pipe and discharging the refuse gases up short stacks or chimneys and outdoors, thus utilizing the waste heat of the gases to heat the feed water for the boilers. Mr. Wm. R. Roney, M. E., of Boston, Mass., is probably the best authority on this form of mechanical draft. The results of his experiments in brief, as lately stated by him, are the first cost of a properly designed mechanical exhaust draft plant is very much less than that of a suitable chimney of equal capacity, usually averaging 75 to 80 per cent. less; and as to power required for fan propulsion in a plant with 6000 H. P. water tube boilers, the power required to drive one fan to do this work was 6-10 of 1 per cent. of the boiler horse power developed or estimated in coal per horse power per hour at $3.00 per ton; the fuel cost of running the plant one year was 2 per cent. of the estimated cost of a natural draft chimney for the plant. In other words, it would not pay to build a chimney so long as money was worth more than 2 per cent. per annum. In another case the power required was less than 10 H. P. for each 2000 H. P. produced, or less than half of 1 per cent. of the power developed by the boilers; and in a tabulation of the results obtained in nine large plants the average net fuel saving was about 15.2 per cent., and in some nearly 20 per cent.; and, in addition, there was the economy in first cost and in the money which would otherwise have been invested in chimneys.

Referring to those feed water heaters commonly known as fuel economizers, they are certainly no new thing, having been manufactured in England for over fifty years and in this country for three or four years, and have been imported for many years. They have been used, however, almost exclusively in chimneys with natural draft, and hence on account of the reducing effect on the draft caused by lowering the temperature of the gases and retarding their flow it is always necessary to provide a better draft where they are to be used than when not; hence, higher and larger chimneys. Good practice requires that chimneys with economizer should never be less than 200 feet in height. Certainly, the failure which has sometimes attended the introduction of the fuel economizer has often been due to placing them where the chimney draft was none too good before; hence, they not only failed to show an expected economy, but also impeded what draft there was. Of course these objections do not hold when mechanical draft is used; a short chimney can be used only high enough to permit the discharged gases to clear neighboring buildings, and the heating surface in the economizer can be made a maximum and the gases cooled to a point which would destroy the draft altogether in even the tallest

chimney using natural draft. In the designs of new plants and chimneys for same this point of small chimney required is extremely important in first cost, especially in this day of valuable land around our city power buildings. Mechanical draft possesses great advantages over natural draft, especially in its flexibility of application and adaptation to both large and small capacities and in its ability to meet sudden and excessive demands for steam either by an extra turn of the throttle valve or by use of an automatic regulator controlling the steam supply to the fan engine, and hence adjusting the speed of the fan according to the boiler pressure. No such flexibility of adjustability can be had with natural draft. It should be noted that in no system of exhaust draft so far referred to in this paper does the suction fan handle the furnace gases at their furnace temperatures; they pass through the fan after the major portion of their heat is absorbed by the economizer or by the "abstractor," or air supply heating device, the average temperature of the gases actually handled by the fan, even with the exhaust draft, being about 300 degrees, a temperature in no way deleterious to a fan of proper construction with "a water cap" bearing. The Howden "hot draft" apparatus has been applied quite successfully on the lake and ocean boats; this consists of a blower fan forcing cold air at about $1\frac{1}{2}$ ounces pressure over tubes (through which are passing the hot gases from the boiler furnaces), and thus absorbing most of the heat from the furnace gases, thence discharging this hot feed air at about $\frac{1}{3}$ to $\frac{1}{2}$ ounce over and under the grates. Tests of these plants on the lake steamers "Madagascar," "Nicaragua," "Harvey H. Brown" and others have, on a comparison of comparative fuel consumption per ton cargo carried per mile, showed a gain in efficiency of 28 per cent. over work done without the hot draft and using a poor grade of bituminous coal; and showed an average combustion of 1.65 pounds fuel to each indicated horse power developed per hour, a most remarkable showing for the mechanical hot draft, as well as for the complete steam plants. The Ellis and Eave's system, as applied to the power plant for the American Line of steamers in New York city is on the same principle as the Roney exhaust draft plants, excepting that, instead of the feed water heating economizer, a feed air heater is used and hot air supplied to boiler; and for this system a gain of 20 to 25 per cent. is claimed, and certainly 15 to 20 per cent. can be relied upon.

Before closing this review of the most important systems before the public to-day the "Keene Fuel Economizer and Smoke Consumer," a form of mechanical draft, demands attention. This device consists of a fan blower taking in ordinary air on one side

and connected by means of a suitable pipe with a chimney flue near the breeching of the boiler on the other side, so as to take in more or less of the flue gases to heat the air, and delivering the mixture of air and gases to the ash pit of the furnace, whence they are forced through the grates and the fuel bed. Dampers are placed on each side to regulate the proportion of air and flue gases admitted to the blower. Tests of this apparatus under direction of the smoke commission of the city of St. Louis, Mo., showed an average temperature of the air discharged under the grates of 235° and a gain in efficiency over the same boilers without the device of 38 per cent.; and when using the fan, but not heating the air supply, a gain in efficiency of 26 per cent. and a smoke record of reduction of smoke emitted from stack of 90 per cent. is claimed. It will be noted from the above matter that the simple "forced draft" application of mechanical draft, consisting of a blower discharging ordinary air under the grates of the boiler, has not, so far, been largely touched upon. But there are twenty of these applications, however, to one of the more elaborate economizer or hot draft arrangements, and the proportion is probably much larger. There is no doubt whatever but that the addition of the special features referred to for further increasing the economy of the mechanical draft plant do so enhance their value, but there are, as before stated in this paper, a vast number of boiler plants already installed, and mostly of small size, whose efficiency is susceptible of increase and oftentimes badly in need of such an increase by the addition of the simple forced draft, and where the cost renders the same the only available apparatus. Great corporations, with their hundreds of thousands involved, can afford the most complete equipment and profit by the same, but the smaller steam users must often, and very often, purchase the lowest in price that they can get, and still improve their poor draft or abate their smoke nuisance, or both. A description of a few representative plants of this kind will be of interest. The elements are about the same in all cases, excepting in very small outfits of 30 horse power or under.

A steel plate fan with direct connected, single or double engine, usually vertical, exhausting the air from the hottest part of the boiler and engine room (thus serving to help cool the room, as well as assisting the boilers), discharges this air under the grates in case of stationary land boilers, or into wind boxes in front of ash doors for marine boilers, with suitable dampers and levers readily accessible for operation of same. An automatic steam regulating valve on the steam supply pipe to the engine for the automatic regulation of the engine speed in proportion to the pres-

sure desired to be carried on the boilers is generally provided. The velocity of the air at the fan outlet is carried at from $\frac{3}{4}$ to $1\frac{1}{2}$ ounces pressure, and under grates from $\frac{1}{3}$ to $\frac{3}{4}$ ounce; and a delivery for tubular boilers of about 150 cubic feet of air per square foot of grate surface per minute, and for water tube boilers from 200 to 300 cubic feet per square foot grate per minute is effected. A plant like this, with a 70-inch (narrow fan) and five by seven single engine was placed in the power and light room of the large dry goods store of Barnes, Hengerer & Co., of this city, about two years ago by the Buffalo Forge Company; has run successfully ever since with no unusual repairs, and has shown a net saving of at least 30 per cent. in the fuel bills and a relative gain in efficiency of 10 to 15 per cent., with a practical abolition of the smoke nuisance. The remarkable economy in the fuel bills arises in this case from the fact that before the introduction of this system the best pea coal and anthracite was burned, while with the use of the forced draft apparatus a soft coal slack is used, with the addition of one barrel of good hard coal to about six or eight of the slack or cheap coal. Plants have been installed in the Genesee and Broezel Hotels, about twenty factories and manufacturing establishments and on the lake steamers "Wm. H. Gratwick," "Caledonia," "Italia," "Bulgaria," "Australasia" and others, with practically the same results, by the same firm. The illustrations herewith show the method of application.

As a conclusion it is pertinent to emphasize the fact that the most perfect mechanical draft plant will be a failure nine times out of ten if the firing of the boilers is not properly attended to, and the too rapid rushing of the air through the grates or the improper impeding of the draft by the kind of firing and the manner of stratifying the coal on the grates is not prevented. Engineers may design, and inventors may scheme, but the king of the boiler room is the fireman. Mechanical draft is a help to the fireman as well as to the man who pays the coal bills, if he would but appreciate it. The day of the tall chimney, belching forth its clouds of black smoke, which many a time has been cited as glorious evidence of prosperity, is about over, and the day of the development of one indicated horse power by one pound of coal, with all its enormous economies to the steam-using world, approaches, and no single agency in this good work deserves more praise or has been more useful than mechanical draft.

DISCUSSION.

MR. RODGERS.—The speaker struck the keynote when he said the success of any method depended upon the fireman. I, how-

ever, take exception, and desire an opportunity to discuss it at another time.

Mr. Holloway.—What is wanted is perfect combustion, no matter how it is obtained. Even the best appliances are dependent upon careful handling.

ADDENDA.

Howden Hot Draft.

Report of chief engineer of Goodrich Transportation Company, of Chicago, showing results of fitting three of their steamers with this form of mechanical draft. During season of 1893 the steamers used Pittsburg coal without the Howden draft, and during season of 1894 they used Indiana coal (which could not be burned before) and with the Howden draft:

Str. Indiana.	Miles run.	Tons of coal used.	Cost.	Pounds of coal per mile.	Saving.	Cost per mile run.	Saving.
Season,							
1893	24,870	2,795	$9,191.90	224.7		.37	
1894	24,500	2,633	5,641.57	214.9	5 pr. ct.	.23	38 pr. ct.
Str. Racine. Season,							
1893	23,660	2,350	8,759.71	198.7		.38	
1894	22,770	2,000	3,987.50	175.7	12 pr. ct.	.18	50 pr. ct.
Str. Atlanta. Season,							
1893	23,615	2,791	8,903.40	238.		.38	
1894	22 680	2,320	4,838.44	205.	15 pr. ct.	.22	40 pr. ct.

Mechanical Exhaust Draft with Feed Water Heating Economizer.

Report of Wm. R. Roney, M. E., of Boston, Mass., on test made.

The per cent. saving is only a comparison, using same kind of coal. Undoubtedly a comparison of fuel cost between necessary kind of fuel to use without and possible kind to use with the exhaust draft would show a saving of 30 to 50 per cent.

Test of economizer and mechanical draft plants, showing initial and final temperature of flue gases and feed water in degrees Fahrenheit.

Plants tested.	Gases entering economizer.	Gases leaving economizer.	Water entering economizer.	Water leaving economizer.	Gain in temp. of water.	Fuel saving per cent.
1	610	340	110	287	167	16.7
2	505	212	84	276	192	19.2
3	550	205	185	305	120	12.0
4	522	320	155	300	145	14.5
5	505	320	190	300	110	11.0
6	465	250	180	295	115	11.5
7	490	290	175	280	105	10.5
8	495	190	155	320	1[illegible]5	16.5
9	541	255	130	311	181	18.1

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. AUGUST, 1899. NO. 2.

FOREST MANAGEMENT IN MAINE.

BY AUSTIN CARY, A. M., FORESTER TO THE BERLIN MILLS CO.

[Read before the Boston Society of Civil Engineers, May 10, 1899.*]

IN any broad view of the forest interests of Maine we should begin with topography. The ruling topographical feature of the State is a broad plateau† stretching from west to east, dividing its area into a northern and a southern slope. Of these slopes the northern is the smaller, embracing the watershed of the St. John River. The southern slope is a belt along our entire coast line on the average 140 miles wide.

A further feature to be noticed is the fall of the divide from west to east, from the foot of the White Mountains, in New Hampshire, to Mars Hill, on the borders of New Brunswick. The Rangeley Lake system at the west is between 1400 and 1500 feet above sea. Moosehead Lake, at about the center of the line, lies at 1020 feet. The highest point on the boundary between Maine and New Brunswick is about 500 feet above sea level.

The botanical features of the State hang largely on the topography. In the southwest, for instance, a large district, low-lying and with a mellow soil, is united botanically with Massachusetts and Southern New Hampshire. Oaks are prominent in the woods here, and white pine was the staple of the original soft wood timber. On the other hand, the plateau country presents a Canadian flora. The hard wood trees are the birches, maples, etc., characteristic of

*Manuscript received July 11, 1899.—Secretary, Ass'n of Eng. Socs.

†For the original statement of these relations, and valuable information as to Maine's natural features and resources, see Wells' "Water Power of Maine."

a colder region, and spruce forms the largest and most valuable part of its soft wood timber. In the west, where the boundary of the plateau is sharp, and where it has its greatest elevation, the contrasts in timber stand are greatest. Eastward, with the easier topography, there is more variety and mixture.

We must next observe that a large part of the State of Maine is destined to remain permanently wooded. The bulk of our population is now and will continue to be located in the lower southern part, where milder climate, abundant water power and areas of fertile soil offer advantages. Again, there is a strip of land with easy topography and very fertile soil along the New Brunswick line in Aroostook County. Out of these areas indeed a large proportion is wooded, and some bodies of land included within them are of such a character that they never will be inhabited or cultivated. For the great district remaining, about half the area of the State, the same thing is true. It is high in the first place, and the season of growth is short. As a rule the topography is rough and the soil poor. Considerable of it, indeed, is little more than ledges and piled up rocks.

Half the area of the State, then, about 15,000 square miles, seems destined to be permanently forest. This is an area twelve times as large as the Black Forest* in Germany. The States of Massachusetts, Rhode Island and Connecticut, taken together, just about equal it in area. The importance of this body of land as a source of wood material is evident from the statement. The relation to it of business development will be seen later on.

Since its settlement Maine has always had a lumber business; that is to say, lumber has been cut and sawed here not only for local consumption, but to export to other communities. Many of the earliest settlements in the State were built about accessible mill privileges, and later movements of population have in considerable measure been related to woods and mills.

The development of the lumber business has proceeded according to evident laws. In the natural condition pine was at once the largest, most valuable and most accessible timber that the State possessed; pine, therefore, was the first timber to be taken. It was taken, too, where most easily accessible, along the coast and on the banks of the rivers, where it could be floated to mills, run by tide or located at the first powers above their mouths. As the best class of timber failed in the first locations men pursued it further up the streams, or spread along the coast to other regions which had not yet been drawn upon. For a long period, however, they cut

*The amount of actual forest land is here meant, not the gross area.

only pine, even after they had to go long distances for it. In fact, the State had been settled nearly two hundred years, and the larger rivers had been culled for pine clear to their sources on the plateau, before there was a profitable market for other soft wood timber. At length, however, the limits of the pine supply, a supply never so abundant per unit of area in the northern wilds as in the low-lying parts of the State, began to be approached, and spruce began to take the place of pine as the staple of lumber export.

Since about 1840, then, the bulk of the lumber exported from Maine has been spruce, which was cut in the great forests of the plateau and sawed at mills located low down on the Penobscot, Kennebec and Androscoggin Rivers. Since the early 70's, however, the saw mills have had a competitor in the log markets of the State in the shape of mills manufacturing wood paper. Beginning about 1870 in a small way, pulp and paper manufacture rapidly increased, and in ten years had become well established. After a period of experimentation spruce wood was settled upon as by far the best technically for most uses, and it is now exclusively used in most mills. The amount of this use can be judged of from the mill capacity. In 1894 the pulp and paper mills of Maine numbered forty, and represented, as reported to the State Labor Commissioner, an invested capital of $12,000,000. They employed between 4000 and 5000 men, and had a daily capacity of 397 tons of paper and 765 tons of pulp. At the beginning of 1899 the mills of Maine reported to the directory of the trade a daily capacity (not production) of 650 tons of paper and more than 1000 tons of pulp. In this respect Maine stands second only to New York among the States of the Union.

Here we get at what is at once the big and the pressing matter in connection with the forests of Maine. Paper making is one of the great, stable and growing industries of the country. It is mainly dependent on spruce wood because spruce excels in length and strength of fiber, and is most readily reduced to the macerated condition. Now the woods of Maine possess the largest stock of spruce wood existing within the limits of the United States, while probably in a still greater degree they embody growing capacity. The question what that resource amounts to, the question, too, how it is being used and what may be done to foster it, are questions of concern to the whole country.

The people of Maine have been behind in the appreciation of their natural resources. The State is approximately 31,500 square miles in area. Wells in 1869 estimated, excluding water and cultivated land, that two-thirds of it, or 21,000 square miles, was covered

with woods, and the conditions since then have not greatly changed. The area destined to be permanent forest, as earlier defined, we may set at about half the area of the State, or 15,000 square miles. Probably more than that, even taking out waste areas in the shape of burnt land and barrens, now possesses spruce of at least some small value. As to amounts of timber standing, no careful summaries have ever been made, except for some comparatively small portions. Much of the country never has had the timber upon it estimated, and if that had been done a vast amount of digestion and re-exploration would be required before the figures could be safely compared and summarized. The best that can be done here to give an idea of the condition of the Maine woods is to describe very generally and cursorily different tracts of country.

Some 12,000 square miles on the St. John and upper Penobscot are timber land of very varying quality, containing every variety of stand natural to the region. Considerable areas in the aggregate have never been cut for spruce, and the cutting that has been done has generally been for saw logs of good quality merely, and pretty loose and unsystematic. The area named has not been seriously damaged by fire. Here, due to its area rather than quality, is the great supply of spruce wood now existing in the State.

The Kennebec River drains 5800 square miles, but less than half this area could be classed now as actually spruce producing. But at the heads of the streams, in very difficult situations, small tracts yet remain that never have been cut for spruce; but the remainder has been cut through, much of it severely and several times over, while both in early and more recent years the region has suffered severely from fire.

The Androscoggin River possesses about the Rangeley Lakes the best spruce timber land in the State. It has been saved from fires, and, due to the roughness of the land, much of it has thus far escaped cutting. The drainage is of small area, however, 2750 square miles in Maine, and half of that, in the lowlands of Southwestern Maine, cannot be considered as spruce producing. There is also a great mill capacity located in this region. At Berlin, Livermore and Rumford are some of the largest paper mills in the world, and while they draw in a considerable portion of their wood supply from Canada and elsewhere by rail, the Androscoggin drainage itself is being called upon for timber at a rate and in a manner that will within a few decades, if continued, blot it out as a source of spruce timber.

Other items of the timber supply of Maine are of minor importance, at least in the present connection. Southwestern Maine has

white pine as its main soft wood growth. This is a quick-growing wood, and on it that part of Maine does a considerable lumber business. This item is seldom thought of in connection with the lumber supply of the State, but, as a matter of fact, wooded lands in this region are probably producing more per acre than the backwoods. Pine, however, is seldom used in the manufacture of paper.

Most of Washington and Hancock Counties, in the southeast, consist of poor and rocky land, fit for nothing else but the growth of timber. This country, however, has been long and hard cut. A good half of its area, too, has been burned over, and while burned land almost always quickly grows up again, fire changes the character of the growth and sets it back as a producer of lumber. As to spruce supply, as available now and in the next fifty years, the main items have been considered already.

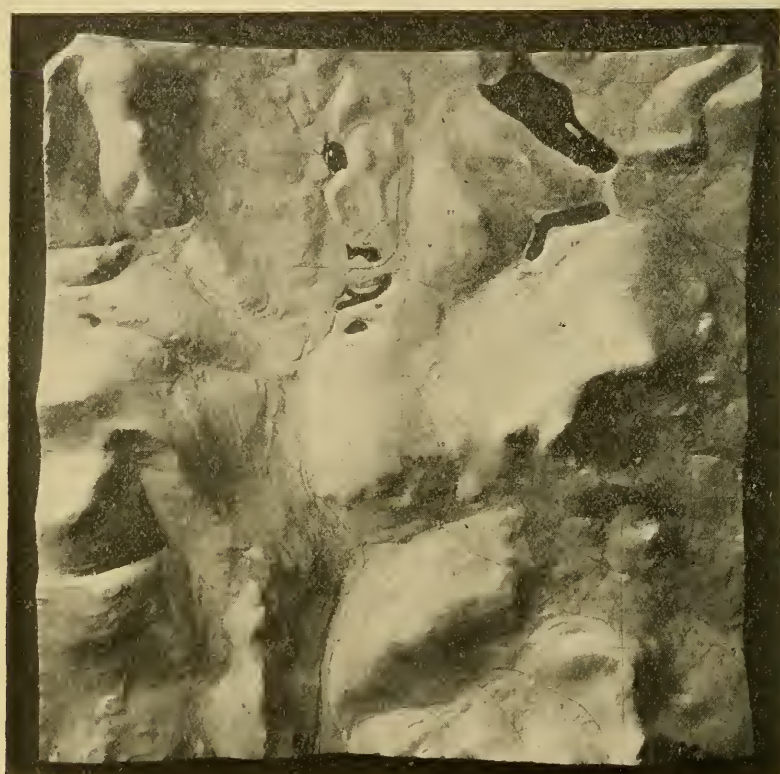
Under the circumstances it is perhaps rash to set any figures for the timber resources of Maine. In stating clearly, however, that such a figure can be merely a rough guess consequences of presumption are deprecated. It seems probable, then, that twenty-five billion feet, board measure, may approximate the amount of spruce wood standing in the State. The total lumber cut in the State in 1896 was something over six hundred millions. Of this probably five hundred millions was spruce. About two-fifths of this went to the paper and pulp mills.

Six hundred millions is equivalent to 30 feet per acre on the gross area of the State. Five hundred millions may be 50 feet per acre on the area of what we might call spruce producing land. These figures are within the amounts which such studies as have been made attach to ordinary cut-over land as its yearly growth. Certainly, they are small in comparison with what we know scientific forestry has produced elsewhere.

The general inference to be drawn from these facts is not a discouraging one. Our resources are still great, and we may feel justified in using them freely. It is to be remarked, however, that paper mill capacity in the State is being rapidly increased at the present time, and promises to reach in the near future a much greater development.

It might be remarked of the foregoing that it is business and not forestry. The reply to that is that whatever forestry we are to get in Maine, at least in the near future, must be worked out under business conditions. The State of Maine is not likely to interfere by law with the conduct of private business. Neither does it appear that State ownership of wild lands to any great extent is

likely to be brought about. Maine is poor in comparison with the States that have inaugurated that policy, while it is not called to that course by such urgency. Agriculture has not, to our knowledge, been affected by the cutting of our forests. The flow of our rivers has not been affected to such an extent as to elicit protest or a call for investigation. The climate of Maine is such that almost all denuded or burned areas very quickly reclothe themselves with growth which, if not valuable at once for timber, at least protects the surface of the ground beneath it.



Topographical model of township No. 3 R. 5, Franklin Co., Maine, showing, in addition to the waters and relief, bogs, roads, trails, section lines, etc.

The man therefore who would throw in his lot with the forests, who would economize in their use and maintain their growing power, must bring himself to bear on the forces in the field. He should not be choice in his weapons. The spread of information will accomplish much, but competition, when it can be brought to bear, may prove a more effective tool. Forestry should seek to

ally itself with business, to promote the success of careful and foresighted concerns. The forester, if he would work directly on the problem of management, must work in private employ and in accordance with its fundamental conditions. First among these is the necessity of making profit. Should the forestry practiced lead to loss, the business goes down and the forester's position and opportunity go with it.

The lay of the land in this quarter will become more evident if we briefly review the systems of landholding and management existing within the State. First is the stumpage-selling system, long current and now in vogue in the timber lands of central and northern Maine. The land title in this case is held by men who neither own mills nor cut logs. Neither, as a rule, are they practical woodsmen. They are simply men of means who have acquired lands by inheritance, or who, having found out that timber land is a safe and profitable investment, have bought it on the judgment of others. They sell lumber standing at so much a thousand, and do not as a rule exercise, either directly or through their representatives, any effective supervision as to how it is cut. The man who buys the stumpage may or may not own mills. At any rate, he is interested in getting as good a lot of logs as possible for the stumpage paid and with the least outlay of time and money. He cuts accessible bunches therefore, and leaves distant or scattering timber. He cuts his stumps as high as is convenient, and throws away a quarter of his lumber in the shape of the knotty tops, which, though capable of use, are of distinctly less value. He slashes through the country anywhere with his roads, and makes no attempt to spare young growth or to save such as is killed if it comes below the class of most desirable timber. In examining these matters a few years ago for the United States Forestry Division I found concerns where only 60 per cent. of the whole volume of trunk wood was saved from the largest and finest trees, and where, taking into consideration the small trees killed and left, the lumbermen put into the water less than half of the timber killed.

Such methods as these are an heirloom from former times, but they are rendered possible in the present only by the system of landholding under consideration. The trouble is the interests of the man who does the work are divorced from those of the land on which he is operating, and that this is not offset by strict contract and supervision. The power of remedy lies with the landowners, who are strong parties and who would benefit by careful handling of their lands. In a few cases this has been done. Thus the only really conservative force on the Androscoggin to-day is a large

body of land held in this way which is operated carefully and with a view to the future. As a rule, however, nothing can be expected from present owners. The only remedy is to buy them out.

Again, landownership in the past has often been a subsidiary part of the sawmill business. Men engaged in lumber manufacture found they could buy land cheaper than logs, and did so, going on often to do their own lumbering. In their cases logging work is frequently somewhat more economical, but it can hardly be said to be more foresighted. The man's object here is to stock his mill. Beyond that the land has no value.

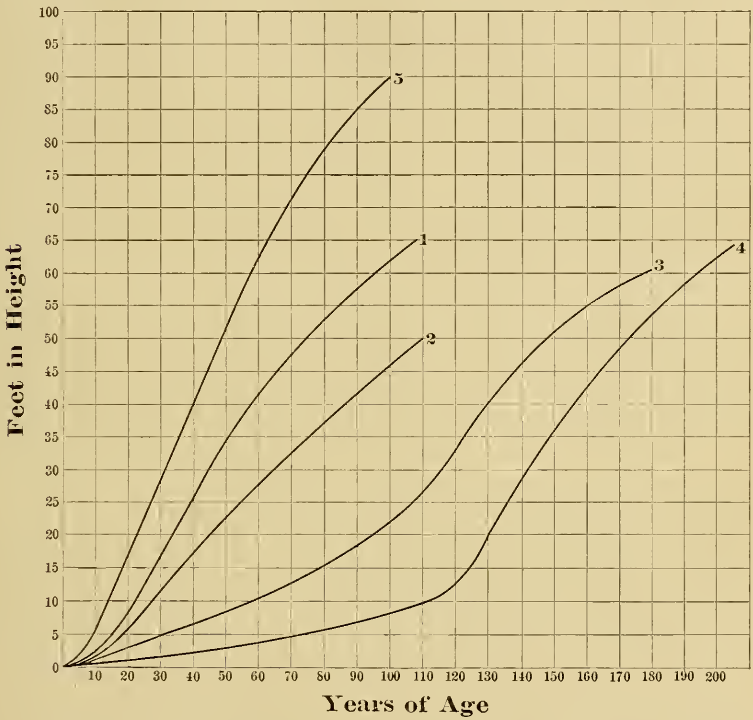
An example here, an extreme one, to be sure, will serve to show what is sometimes lost under the present methods of conduct of the lumber business. I happen to know where a very large amount of spruce timber, belonging to one concern and standing in one compact body, was killed by the ravages of insects. Within two years from the death of the trees there must have been a loss on the lumber not far from 50 per cent. After five years or so there would be nothing there worth going after. And yet, due to stupidity, obstinacy or to financial pressure, no adequate measures were taken to save it. In fact, the dead timber was left to rot, while nicely growing land that had once been cut through was stripped off beside it because logs could be got there a little cheaper. What good forest management consists of in such a case is very evident. The fact illustrates the principle that good forestry is very often identical with sound business. Neither one is possible if there is too great financial pressure.

Whatever the economy of his work, from the point of view of forestry, there is one fundamental trouble with the sawmill man's attitude to his land. He regards it simply as a source of stock for his mill. He buys the land to strip it. He wants to get his money out quickly and put it into some other investment. So he takes principal as well as interest, the stock of wood needed for growth and reproduction, and not merely the mature crop. If, in years back, owing to slack methods and the condition of the market, a good deal of growing lumber has been left standing, that is entirely aside from his main purpose and intention. At present some of our most destructive and thoroughgoing cutting is being done by sawmill men.

Since the pulp and paper mills began to be a strong factor in the log market of the State a good deal of hue and cry has been raised, because they cut or caused to be cut much of the small growing lumber. Small logs could be used by them to quite as good advantage as large ones, while, since they were less desirable

to the sawmills, they could be had much cheaper. There have been, therefore, of late years two classes of logs on our larger rivers, saw logs and pulp, selling at considerably different figures.

The pulp mills have been justly criticised on this head, and yet there are considerations here that should weigh strongly in their favor. They have worked great economy in the use of our forest resources, have taken vastly more from our lands than would have



Height curves, showing comparative growth of spruce and pine and of spruce under different conditions.

1. Curve of spruce grown on good soil,—land cleared by fire.
2. Curve of spruce on very poor soil,—same tract of burnt land.
3 and 4. Curves of spruces grown up in mixed hard and soft wood under shade.
5. Curve of a pine on same site as No. 1.

been possible under the old *régime*. The pulp mill can use the knotty tops; a seamy or crooked tree is as good as a perfect one; the small trees cut or smashed down, which in other times were left to rot, can all be utilized by the pulp mill. Sometimes tracts of land are given a value, and can be operated at a profit for pulp, which would never have been cut for saw timber.

And if, in the direction of economy, the paper mill has vastly raised the standard, it has seemed to promise the same in the direc-

tion of foresight. In beating about among the lumber consumers of the State, as just mentioned, the fact forced itself upon my notice that the men who were thinking pointedly about the matter of timber supply, the men who were most interested in anything that promised to increase and extend the yield from our forests, were the owners of pulp and paper mills. And, on consideration, the reason for this is plain. It is their great investment in mill plant, an investment dependent on forest supplies for life and profit. The contrast with the sawmill business is striking, and, in the present connection, vital. A plant that will convert seven millions of spruce wood a year through the stages of ground wood and chemical fiber into finished paper requires a capital, mostly in the fixed form, of not far from a million dollars. Many of our operating sawmills, on the other hand, represent a valuation of only $10,000 to $20,000. The paper mill man is tied; he is in the business for a long period. The sawmill, when lumber gets scarce or business poor, may be abandoned.

Thus we have had a movement among the paper mills, yet in its infancy, but apparently increasing, to back themselves with land enough to render them independent. With that movement has gone the purpose to treat those lands carefully and with foresight.

In this movement it seemed as if the financial basis might have been attained for conservative forest management, as if we had solved the problem of so disposing of the ownership of our forests that their value might be preserved and the community at large derive most benefit from them. Still more was that hope nourished last year when, at the organization of the International Paper Company, with control of 80 per cent. of the output of news paper of the country, a professional forester was employed, and the intention expressed of living, so far as forest supplies were concerned, within the limits of actual growth. It looked as if the paper mill, backed by forest land, the two operated together as one great permanent investment, was the form in which the bulk of our Maine woods might in time be held. This appeared the more likely because, as many of the mills have been situated, land sufficient to so stock and fortify them could be had for a less investment than the cost of the mills, so that heavy profit from the land part would be a minor matter in comparison with the safety and prosperity of the whole.

We may hope for much from this idea, and yet must be cautious in banking too heavily upon it. It seems sometimes as if American business enterprise were too grasping, reckless and shortsighted to have safely intrusted to it a great natural resource. Heedless desire for immediate gain tends to the overstocking of every profit-

able line, and ruinous prices and cutthroat competition follow in its wake. Thus men reckoning at the very closest on the price of paper are compelled to figure on the price of pulp wood as one element, and if that is done too closely it shuts out the opportunity to do anything for the land. On the other hand, the danger in combination is that business will be conducted with reference to the stock market rather than to sound business success. Either excessive competition or wrongly used combination is destructive of sound, liberal business. Either, in this case, will prevent doing anything to the advantage of the land.

At any rate, as a safe and satisfactory arrangement for the holding and operation of forest land, we have suggested to us the organization of companies of general investors. Forests, carefully handled, form a very secure form of investment, able to pay a moderate return without loss of capital. In Europe forests have proved the safest and surest investment, being used in that way not only by the noble families and others of the best class of investors, but being held for revenue by cities, towns and states. On the other hand, conditions are right here to keep the forest constantly producing. The investor looks only for interest, and wants his capital kept intact. By that means sufficient wood stock for growth and reproduction is left on the land.

There is vastly more in the woods business and in lumbering than might be imagined by the uninitiated. In developing a township of land for the first time the first thing to do is to get a road to it. Along that road, as business is now carried on in the most progressive localities, is strung a telephone wire. Supplies and communication are thus assured.

Next comes usually improvement of the streams. Our smaller streams are generally rough and crooked. Rocks have to be blasted out of the channel, abutments built to run the logs round sharp turns and keep them out of the swamps. Dams are constructed to control and prolong the flow of water. These improvements are costly. Some of them have a short life. They sometimes compel a concern to log heavily on a tract while they are there.

This is but a small part of the expenditure, however. On large lakes logs are towed more cheaply by steamer than by hand. Three steamboats of different sizes and patterns are employed to get past the lakes of the Rangeley system, and booms, dams and piers are needed at various points below. Again, several hundred horses are used in the woods work of the company by which I am employed, so that even in the small matter of harness no small

amount of care is required to keep a supply in stock, to keep run of it in movement and to keep it in repair.

An Androscoggin logging camp contains as a rule forty or fifty men. A woodworker and blacksmith are in every crew to supply it with tools and sleds. Two men manage the cooking, and often another has special charge of the stable and horses. The rest of the crew are divided up by the boss into squads; a teamster with a pair of horses and sled as the nucleus of each, and with him, to do the cutting, a crew of usually four men.

This crew, under present arrangements, works largely by itself. The boss of the whole crew gives it ground to work on, and spots out its main road. He tells the men in general terms what to cut, and visits them once a day to see that they are doing as they were told. Further than that, however, the men run their own work. A man of experience leads off, spotting his road and having a man to help him fell the trees. These two men also cut the log off at the top, cut the limbs off and roll or swing it to where it can be hitched onto by the team. The third man has to trim the knots close, bark the log if necessary, so that it shall drag easy, and, when the teamster comes along, help bind the load onto the sled. The fourth man, meanwhile, is ahead of all his mates, making a road by cutting out the trees and windfalls, filling up the holes, bridging brooks, etc. In our woods the men are mainly French Canadians and immigrants from the British provinces, with some Yankees and a sprinkling of men from the northern countries of Europe. They vary much in experience and capacity. Good men, over and above board, are paid from $20 to $26 a month.

These are the men that the forester has to work with. This is the organization he will have either to utilize or modify in carrying out the purposes he entertains toward the forest. So far this organization has been trained simply to rapid, clean cutting. It has had to get its lumber and get it cheaply, and that is all there is to it.

The forester, in cutting through our spruce woods, wants to leave a stock for reproduction and growth. This, of course, can best be left in the shape of young trees. No one is more interested than the forester in removing, and so saving, all dead timber that can still be used, and also any defective and declining trees. Usually financial considerations will require much more to be taken, probably two-thirds of all the merchantable timber. If so, the forester is as interested as anybody in having that done thoroughly and well. It must be done economically, however, without waste of wood, and it must be done with as little damage as possible to the

young growth which it is desired to retain. And right here, in the matter of saving and protecting the young trees to form a future stock, is where the forester meets his difficulty, both with the men he has in charge and with those who in turn are over him. The way ordinary lumbermen rip, smash and destroy young trees makes a forester sick to the stomach. And, on the other hand, the requirements imposed by his employers in respect to the amount of timber that shall be taken, the form in which it shall be got out and the expense of the operation make it often very difficult to do anything effective for the land. Not the least of the obstacles encountered is the logging boss. As a rule he is very efficient, but having up to the present been a despot in his own domain he is often as opinionated and self-willed an individual as can be met with.

Nothing will convey so clear an idea of the problem involved as comparison and a brief record of experience. In the Adirondacks, under the lead of Messrs. Pinchot and Graves, now of the United States Foresty Division, large tracts of spruce land have been taken in hand, carefully surveyed and examined, and cutting work has been begun in accordance with a carefully studied plan. The ground to be cut through there is traversed the summer before by the forester, and every tree that is to be cut is marked. The cutting itself is very strictly supervised, and no departure from the work marked out is allowed except for the strongest reason. Lumbering methods in the Adirondacks differ somewhat from those of Maine. There is less road cutting. Timber is cut into 13-foot logs where it is felled, and dragged from the stump onto yards by one horse. Now Pinchot and Graves state, in their volume, "The Adirondack Spruce," that in this way they can take out of the forest just such trees as they want, and do practically no damage to the remaining growth. A statement of what they found to be the average stand at Dr. Webb's Ne Ha Sa Ne park will make the matter clear. For spruce alone they found 158 trees per acre under 2 inches in diameter, 75 trees 2 to 6 inches diameter, 37 between 6 and 10 inches and 31 trees 10 inches and over in diameter that would scale about 3700 feet. In reference to these they state that the 31 trees per acre over 10 inches in breast diameter can be cut out and yet leave practically all the 37 6 to 10-inch trees and the 233 of still smaller sizes to form, as they would, a good growing stock on the land.

In my experience of one year under conditions outlined above no such results were attained as that. First, as accounting for that, was the character of the timber stand. Here, for instance, is the average stand of about 15 acres calipered over on one par-

ticular tract. Spruce over 4 feet high and under 6 inches in diameter numbered here 64 per acre. Trees from 10 inches in breast diameter, inclusive, down to 6 inches number 29, and would scale, if cut, about 800 feet. Trees 11 inches and up in breast diameter numbered 47 per acre, and would scale somewhere about 8000 feet. We have here a larger amount of merchantable timber per acre than in the Adirondacks. It is, however, due to size rather than to the number of merchantable trees, while the number of small trees ready to form the succeeding stand is far less than there. To the landowner in consequence the grown timber is of more concern proportionately than the small, and the forester's task of keeping the land stocked is, outside of the natural disadvantages, rendered more difficult.

Again, the forester's work was impeded by the business conditions. The lumber cut on the tract I speak of was to be used, all the largest and best of it, in the sawmill. It was essential, therefore, in order that it might saw to advantage in filling orders for timber, that it be cut long. The logs were, in fact, cut as long as could be driven out of the stream, 35-40 feet. When a tree would make more than that it was sawed into two logs. Now the heavy logs on rough ground required two horses, particularly as they were not being bunched up into small yards for a wagon sled haul, but being dragged often a mile or more directly to the river. Now a road has to be cut out wide for two horses loaded with long logs to get through, and many young trees in consequence are sacrificed. Nor was that the only disadvantage. The weight of a big butt log was heavy for men to handle. It could not be moved far, but trees had to be laid in felling close to the road where the team could get at them, while stuff had to be laid crosswise to roll it on and keep it from bedding down in the snow. Thus in thick timber along a road practically everything would be cut or smashed, and about all that was left would be in the strips between. Much of this could not possibly be helped under the conditions and within reasonable limits of expense. It is often the case that the thinner stands are left with the more promise of growth upon them.

Still, something could be accomplished, and that appears on all accounts worth while. Setting a general size limit of 12 or 15 inches breast high, according to the stand, the crews would go through a country cutting out the dead stuff and the larger timber in a more or less bunchy fashion. On knolls and divides particularly exposed to winds they would be required either to cut everything or let everything stand. The ideal could not be accomplished anywhere. Some timber would be left above the size limit, some

that had no promise of growth in it. On the other hand, more than a third of the small stuff would be cut or smashed down. This, of course, would be hauled and used when large enough to be handled without loss, but it was material which we should have preferred to have grow. As a net result we would leave usually from 1500 to 3000 feet of growing timber on the land.

This is descriptive of a first attempt. In large measure it illustrates how not to do it. It is clear to me that if we are to do anything worth while in forestry our organization in Maine must be tightened up. This is necessary in order to accomplish the purpose of forestry, to leave the land in good shape to grow, but I believe it will pay on the score of simple economy of wood and labor. In particular, if we are to leave our forests in shape to do their best in the way of wood production, the choice of the trees that are to be cut must not be left to ignorant and shifting choppers, but the trees must be marked beforehand by some one who understands the methods and the purposes of the work. In my opinion the logging boss and not the forester is the one who in the conditions of our business here can best do that work.

In adherence to the main purpose of this address, I cannot omit a brief reference to another and in itself a more attractive branch of the forester's business, tree biology and the theoretical grounding of forestry work. Take the matter of tree growth, for instance, the measurement of producing capacity.

Each year's wood growth of a tree is deposited in a ring surrounding on all sides its previous volume. The boundary of each year's growth is usually well marked, and the thickness can consequently be measured. In practice it is better to measure the rings in groups, say of ten each, beginning at the bark. The numbers of rings, taken at several log-cuts along the length of a tree, give us, with the diameter of each section, the means of computing the tree's growth for the last decade or for any preceding period. That gives us the individual tree. Hundreds of such computations, made on trees of different thrift and size, allow us to average, and, taken in connection with surveys of number and size of trees the country over, enable us to estimate the growth in a valley or a township.

From the same observations inferences of great value are drawn as to height growth. If a tree, at the ground, has 200 rings we know that it is, at least approximately, 200 years old. If 20 feet above ground we find 150 rings we know that the young tree consumed 50 years in growing to that height. So on up through the number of sections.

The facts are best represented in graphical form. Thus a spruce growing on a piece of burned land at Moosehead Lake was cut down, leaving a stump a foot high. There were 98 rings in it. Fifteen feet above there were 77 rings in the section, showing that 21 years were consumed in growing that height. Ten and one-half feet higher there were 66 rings, and the same distance above 53. The tree, as cut, was 65 feet high, and, allowing ten years of height growth for the stump, it was grown in 108 years. These facts are represented in curve 1 on the diagram, which will need no further explanation.

The value of this method of representation will be best brought out by comparison. Curve No. 2, for instance, represents the height growth of a spruce which grew in the neighborhood of the other tree, and in the same conditions, except those of soil. It was standing, in fact, on a bed of rocks. No. 5 is the curve of a white pine which grew up with the first spruce, and was of the same age. It shows the rapid production of that species.

Curves 3 and 4 are still more interesting. They represent the growth of spruces which stood in mixture with hard wood in forest whose history had been unbroken for centuries, which had trees of every age and size. Young trees starting in such conditions have to bear shade; they grow slowly for many years, and only perhaps after a century of struggle do their tops get out into free sunlight. And the point is that our spruce can survive and retain its vitality through a long course of such treatment. The tree represented by curve No. 4, for instance, at 125 years of age was only 15 feet high, and contained probably less than one cubic foot of wood. Yet, even by that treatment, the vitality was not crushed out of it. Getting finally free from suppression, it began a height growth equal to that of young trees which never had been suppressed.

Now, study of our spruce timber shows that the bulk of it has come to us through some such history as this. Knowledge of this gives us an important rule for guidance in management. That is, that young spruce in our woods, no matter if they are thin-crowned and seedy looking, yet retain their vitality, and if in our cutting we will at the same time protect them and open them to the light they will reward us for it. This is one great advantage of our spruce. The species is remarkable in this respect.

Last in this line I will present some figures on the volume growth of spruce trees, illustrating what that is in percentage and actual amount. The trees taken for observation ranged from 7 to 14 inches in breast diameter. They were 340 in number, and observed results have been arranged and evened by drawing curves.

Inspection of the last column, the amount of yearly growth in wood, shows that growth steadily increases as the tree grows larger; that up to the largest size here represented there is no slack. From this point of view trees of this size are not ready to cut.

Growth of spruce on thrifty spruce land on the Kennebec River, Maine, in volume and per cent. From third report of the Maine Forest Commissioner:

GROWTH LAST TEN YEARS.

Breast diameter.	Volume of tree.	In diam., inches.	In per ct. at compound int.	Yearly growth in cu. ft.
7 in.	6 cu. ft.	1.1	4.3	.26
8 "	8 "	1.15	4.1	.33
9 "	10.5 "	1.2	3.7	.39
10 "	14 "	1.23	3.25	.45
11 "	17.5 "	1.23	2.9	.51
12 "	21.5 "	1.23	2.6	.56
13 "	26 "	1.22	2.4	.62
14 "	31 "	1.2	2.2	.68

The column next preceding shows the percentage that the year's growth bears to the volume of the tree in the different sizes. Here the course of the figures is the other way. According to the table, a quarter of a cubic foot on a tree 7 inches in breast diameter amounts to 4.3 per cent., while twice as much wood on a tree 11 inches through amounts to but 2.9 per cent. Here the forester is checked by financial considerations. The larger he lets his trees grow the smaller is the rate of interest earning on his capital.

Much might be brought out in this connection. I will draw only the practical inference that one prime object of the American forester, who will be required to gain as rapid returns as possible, must be to change over the stand as nature gives it to him, with its large trees and comparatively small rate of accretion, into a thick stand of smaller timber more quickly growing and reproducing. That is particularly applicable to spruce when it is to be used in paper manufacture.

For the present, however, all these matters will be secondary in the mind of the working forester. Conditions vary through the country, and everywhere investigation and instruction have their field. But the man who, in conditions similar to those of Maine, is bent directly on the task of bringing forestry actually to pass, will endeavor to secure first the right financial conditions for his work, and secondly to so organize woods work that it will carry out his purpose toward the land in lines both simple and plain.

I wish to present one more topic, a topic of an engineering nature. Men of your training do not have to be told that topography determines very largely the course of all woods work.

Neither do you require to have explained the usefulness of a topographical map. Every lumberman is a topographer in a sense. Clear knowledge of topography is essential to the man who, from a central point, directs the conduct of a large business. So far in the lumber business each man has learned his own topography by cruising, and has carried it in his head. The limitations of this system are evident. Such knowledge is inaccurate in the first place. Then it is likely to be forgotten, and it cannot be conveyed to another man. The loss is particularly evident when one manager drops out of a business and his successor has to acquire his knowledge of locality all over again.

In the autumn of 1896 I had the good fortune to be sent by the Hollingsworth & Whitney Co., of Waterville, Maine, to make what I suppose is the first genuine topographical survey ever made of a New England timber township. The results, in the shape of a contour map and a model, proved so much of a satisfaction to the company and its superintendent that other concerns were led to desire the same thing. Thus I have been employed to survey in all about 125,000 acres. I think, furthermore, that in the economy of the spruce forests of New England topographical mapping has come to stay. A brief description of the methods employed in this work, developed as they have been in the work itself, with the aid of such hints and helps as could be got from outside, may be of interest to members of the Society.

The basis of the height work is leveling. If possible, connection is made with points known from railroad levels or otherwise, giving thus elevation above sea; then a line of levels is run over roads, or whatever else may be the best route to run on, to the ponds and other suitable marks well distributed through the township to be surveyed. From the points so determined by level I work off with aneroids, returning for correction as often as may be to some accurately known point. Two aneroids are usually carried; a thermometer is read with them as often as necessary, and changes of pressure due to the weather are recorded meanwhile by a barograph run by an eight-day clock located at the main camp.

The low accuracy of aneroid measurement is well known, but when carefully used with the aid of the accessories noted above, the aneroid suffices entirely for the purpose. A timber land manager does not require to know, for instance, exactly how high a given mountain is. The approximate relation of things is what he wants. The areas of valleys, the positions of streams and divides, the shape and steepness of the land, the grade of future roads,—these are essential points. Then the passes and their neighborhood often

require especial looking over, because it is sometimes very desirable to haul timber from one drainage to another, if that can be done without too much uphill work. In getting at all these points a land level has frequent use, in addition to the aneroid, or, better still, an Abney clinometer.

In these surveys the land has ordinarily been blocked up ahead of me into mile squares. It is a great advantage if, when the lines were run, marks were left every quarter-mile. Then one can locate himself quite accurately on a line by pacing and without going very far. These marks serve also as the starting point in examining the interior of a lot. For instance, after having traversed the lines of a lot, noted the crossing of brooks and divides, taken the height of essential points and noted or sketched whatever topography could be seen, I might start from the middle of one side to run a line across the lot. In doing this I often use a staff compass with 3-inch needle and folding sights, but perhaps more frequently a common pocket compass with needle less than 2 inches long held in the hand. Indeed, direction can sometimes be held more closely with the latter instrument. For instance, a man climbing over the *débris* left by cutting or shoving his way, head down, through dense thickets of young fir loses direction in the course of a few rods. Now if he has a compass in hand he will stop and look at it. He will do so less often if he has to set a staff, level his instrument and wait for the needle to come to a stand.

Meanwhile distance is kept by counting steps. Six or seven years ago, when I first tried to keep run of distance in this way, in retracing old woods lines, I found I required about 2400 steps to the mile. Later on, either because with practice I became longer gaited or because, without knowing it or meaning to, I discounted more, the number required became less. I found at one time that I was using 2200, and finally I got down to 2000 to the mile. There I expect and desire to stay, because at that rate notes plot so readily. In field sketches and in final maps I have so far used a scale of 4 inches to the mile. On that scale, at 2000 steps to the mile, 100 steps are two-tenths of an inch, and a half-inch square, or a piece of ground 250 steps on a side constitutes 10 acres.*

By one who has practiced it, measurement by pacing can be made, even in rough land and bad walking, much more accurately than would be supposed. One travels along, looking at the country, keeping his count in some back corner of his mind. Every

*Much help has been received on this and other points from the methods of the U. S. Geol. Survey in Michigan and Wisconsin, as communicated by Prof. W. S. Bayley, of Waterville, Maine.

hundred passed is marked down or scored by breaking an elbow in a tough twig carried in the teeth or hand. When a brook is passed or a change in the land occurs note is taken, the barometer read and the count begins again. Steps taken to get round obstacles are not counted, and on strong slopes discount is made. On very steep ground, indeed, steps taken are not a guide to distance, and judgment has to be resorted to in order to fill in the count. As first remarked, however, long practice enables a man to reach greater accuracy than would be supposed. Thus I am seldom out over 100 steps from the 2000 in crossing a lot. The count tells me when a line is approached, and enables me to pick it up with certainty, though it may be blind. Then I go right or left till I hit a quarter-post, and so ascertain the variation from the true compass course. By this means locations are made with considerable accuracy along the whole line.

What has been said makes it evident that a pedometer in just this kind of work can have but little use. It answers very well in smooth going, but its readings are no guide to distance on rough land. In my work it has been used merely as a matter of interest to estimate the number of miles traveled in a day or on a whole job. It is, in fact, a good deal of satisfaction after cruising a rough township, perhaps half-covered with brush heaps and blow-downs, to figure up and tell the company just how far I have been.

On simple ground running once across a lot serves, with a traverse of its boundaries, to give topography sufficient for the purpose. Elsewhere there are roads and streams to locate and divides that should be carefully put in. Here compass and pacing are still used, tying in to the lines as often as may be. Travel in parallel straight lines, however, has advantages if it is sufficient for the immediate purpose in hand. It is more accurate, in the first place. Secondly, if, as will no doubt be usual, the timber land topographer also understands timber, and is expected to report on its character and amount, systematic travel of this kind insures his seeing a fair sample of all the land. Timber estimates in the past have been notoriously inaccurate and misleading in their results, and one great cause of this has been that the men who made them did not see all the land. Of the accessible parts, perhaps of the good parts, they saw too much. They did not fairly balance the whole or correctly allow for the waste land. One man of my acquaintance, realizing that fact, says that in looking over land for purchase he makes it a practice to go first where no timber is to be found. Better than that is some systematic arrangement that causes one to see a sample of every part, and travel in straight lines evenly spaced will do it.

So far our maps have been constructed on the scale of 4 inches to the mile, and 50-foot contours in the rough land with which we have to deal serve to represent the topography. In addition, as a result of the examination, timber maps are constructed showing the character of the growth and the amount of merchantable timber judged to be standing on the land. On these sheets the progress of the cutting can be drawn in succeeding years. These timber maps are of transparent tracing cloth, so that they can be laid over the topography and the two seen in relation. Lastly, since contour maps are not easily read by most woodsmen, topographical models are constructed out of cardboard or veneer. These are perfectly comprehended by any person. With their aid a contract can be let or plans of work talked over in the office with the same clearness as to main features as if men were on the land.

The survey and mapping of a township six miles square has ordinarily cost me about two months' work, two weeks in the office and six in the field. A township can be gone over conveniently from about four camps. If there are on the land places to live in the topographer requires the help of but one man.

POWER DEVELOPMENT AT NIAGARA FALLS OTHER THAN THAT OF THE NIAGARA POWER CO.

By W. C. Johnson, Member of the Engineers' Society of Western New York.

[Read before the Society, February 3, 1896.]

Within the past five years a company has been engaged in the development of water power at Niagara Falls, about whose operations much has been said and written.

The plan which this company was organized to carry out involved the construction of a long tunnel under the city for a tail-race, and the sinking of shafts into the rock to a depth of 150 to 175 feet in which to place its wheels.

This work was necessarily costly and many difficult problems arose in its execution.

The problems have been solved and the work executed in a manner which reflects great credit upon the eminent engineers who have made up the consulting board, and upon the able engineers who have had charge of the execution of the different parts of the work.

Those of us who have followed the progress of the work, as most of us doubtless have done, I imagine scarcely know whether to admire most the good judgment shown in the employment of engineering talent or the wonderful skill in advertising. The newspaper fraternity have turned themselves loose on this work. The adjectives "vast," "grand," "stupendous," etc., have been liberally thrown into every item, but not always with discretion.

One of the most glaring absurdities in connection with the mass of popular writing about this work has been the use of the phrase "Harnessing of Niagara," and the statements, in big headlines, that power would be turned on at Niagara on a certain date (which date was, by the way, several times changed), when the facts are that at the time when the first shovelful of earth was taken out in this work more water power was in use at Niagara Falls than in but few other places in the world, and by far the most powerful wheels in the world were in operation there.

Power at Niagara was turned on in 1725, and, during most of the time since, its force has been utilized to turn water wheels.

It is to these other and earlier developments that I will call your attention to-night.

The first use of power at Niagara was about 1725, when the

French erected a sawmill, near the site of the Pittsburg Reduction Company's upper Niagara works, for the purpose of supplying lumber for Fort Niagara.

In 1805 Augustus Porter built a sawmill on the rapids. In 1807 Porter & Barton erected a grist mill on the river. In 1817 John Witmer built a sawmill at Gill Creek. In 1822 Augustus Porter built a grist mill along the rapids above the falls. From that time to 1885, when the lands along the river were taken for a State Park, a considerable amount of power was developed along the rapids by a canal which took the water out of the river near the head of the rapids and followed along nearly parallel with the bank of the river.

Mills were built between this canal and the river and a part of the 50-foot fall between the head of the rapids and the brink of the falls was utilized. A paper mill was also built on Bath Island.

In 1847 Augustus Porter outlined the plan on which the present Hydraulic Canal is built.

In 1852 negotiations were commenced by Mr. Porter with Caleb J. Woodhull and Walter Bryant, and an agreement was finally reached with these gentlemen by which they were to construct a canal and receive a plat of land at the head of the canal having a frontage of 425 feet on the river; a right of way 100 feet wide for the canal along its entire length of 4400 feet, which is through the most thickly populated part of the city, and about 75 acres of land near its terminus having a frontage on the river below the falls of nearly a mile.

Ground was broken by them in 1853, and the work was carried on for about sixteen months; it was then suspended for lack of funds, and nothing more was done until 1858, when Stephen N. Allen took up the work and carried it forward for a time.

After that, Horace H. Day took up the matter, and in 1861 completed a canal about 36 feet wide and about 8 feet deep.

The location of the head of this canal was the best that could have been chosen. From the head of the rapids it is but a short distance to an island (Grass Island), which extends a considerable distance along the shore, and for a considerable distance above the island the water is very shallow.

In this short space, between the head of the rapids and the foot of Grass Island, the entrance of the canal was located.

Owing probably to the disturbed financial conditions occasioned by the War of the Rebellion, and other causes, it happened that no mills were built to use the water from the canal until 1870, when Mr. Charles B. Gaskill built a small grist mill on the site of

the present flouring mill belonging to the Cataract Milling Company, of which Mr. Gaskill is president.

In 1877, the canal and all of its appurtenances were purchased by Mr. Jacob F. Schoellkopf and A. Chesbrough, of Buffalo, who organized the Niagara Falls Hydraulic Power and Manufacturing Company, of which Mr. Schoellkopf is still the president.

Since that time the building of mills has gone steadily forward. The following is a list of the mills using water from the canal:

Central Milling Company use	1,000	horse power.
Schoellkopf & Matthews use	900	" "
Pettebone-Cataract Paper Co. use	1,300	" "
Cataract Milling Company use	400	" "
T. E. McGarigle, Machine Shops, use	12	" "
City Water Works use	155	" "
Pittsburg Reduction Company will use	3,000	" "
Cliff Paper Company use	2,500	" "
Will use in 1896 additional	300	" "
Niagara Falls Hydraulic Power and Manufacturing Company, use	280	" "
Rodwell Manufacturing Company, Niagara Silver Company, use	75	" "
Carter Crume Company use	39	" "
Francis Manufacturing Company use	10	" "
The Kelley-McBean Company use	5	" "
Oneida Community Co., Limited, use	300	" "
Niagara Falls and Lewiston Railroad use	150	" "
Will use in 1896 additional	350	" "
Niagara Falls Brewing Co. will use in 1896	250	" "
Total	11,026	" "

Mr. Porter's contract with Woodhull & Bryant only conveyed the lands to the edge of the high bank of the Niagara River, and did not include the talus or slope between the edge of the high bank and the river, and only granted the right to excavate down the face of the bank 100 feet.

At that time it was not considered that any higher head could ever be utilized, because it was not thought that wheels could be built to stand the pressure of a higher head; in fact, none of the mills attempted to use more than 50 or 60 feet head. For this reason it happened that although the capacity of the canal as at first constructed was sufficient for some 15,000 horse power its capacity was exhausted and only about 7000 horse power produced.

The flouring mills of Schoellkopf & Matthews, Cataract Milling Company, Central Milling Company, the Pettebone-Cataract Paper Company, the City Water Works, and the factory of the Niagara Wood Paper Company, which is not now running, leased

the right to draw certain quantities of water from the canal and constructed their own wheel pits, and put in their own water wheels.

Two different methods were adopted for constructing the pits for these various mills. In some cases a shaft was sunk in the rock at some little distance back from the edge of the bank, in which the wheels were placed, and a tunnel driven from the bottom of the shaft to the face of the bank for the discharge of the water after it had passed the wheels. In other cases a notch was cut into the face of the bank and the wheels placed in it.

In all cases turbine wheels of different makes, running on a vertical axis, were used.

In 1881 the Niagara Falls Hydraulic Power and Manufacturing Company put in a power plant for the purpose of supplying power to customers, delivered into their mills. The method adopted was as follows:

A shaft 20 x 40 feet was sunk to a depth of about 80 feet, and about 200 feet back from the face of the high bank; from the bottom of this shaft a tunnel was driven to the face of the bank for a tailrace. The water was conducted to the bottom of this shaft in iron tubes, and used on two different turbines running on vertical axes.

The power developed by these wheels—about 1500 horse power—was transmitted by shaft, belting or rope drive to various customers, all located within 300 feet of the wheel pit.

About a year ago a turbine wheel of a capacity of 600 horse power, running on a horizontal axis, was put in this same wheel pit, the power transmitted up to the surface by means of a manilla rope drive, and there used to run electric generators, from which power is being transmitted to various small consumers.

In 1886 the Niagara Falls Hydraulic Power and Manufacturing Company secured a deed of portions of the slope between the high bank and the river, and have since secured other portions, so that they are now at liberty to use this slope for mills and power houses. In this same year I was appointed engineer of the company, and have been in charge of all the improvements made since that date.

The advance in water wheel construction, and especially the development of the possibility of transmitting power by electricity, has made this lower slope one of the most valuable parts of their holdings.

In the spring of 1892 the Cliff Paper Company, being desirous of increasing their plant by adding a wood pulp mill, to use about 2500 horse power, leased sufficient water from the Niagara Falls

Hydraulic Power and Manufacturing Company, agreeing to take it from the tunnel through which water was discharged from the outlet of wheel pit just described, and I was employed to design and superintend the construction of the plant.

For the purpose of getting the machinery requiring the largest power near to the wheels, it was decided to build a mill on the lower bank near the water's edge, and to place the pulp-making machinery in it, preparing the wood on the top of the bank, lowering it down ready for grinding and elevating the product.

To divert the stream of water flowing through the tunnel and confine it for use in the new mill, a short tunnel was driven into the face of the bank at a point about 20 feet below and 12 feet to the left of the mouth of the old tunnel.

From the mouth of the new tunnel an iron pipe 8 feet in diameter was laid along the slope of the bank, connecting with the tube 10 feet in diameter in the basement of the lower mill. From this tube the water is brought to the wheels on the first floor. Provision is made for the discharge of water into the tunnel direct from the canal in case the discharge from the wheels does not furnish a sufficient supply.

Owing to the contracted channel of the river below the mill, there is an extreme fluctuation in the water below of about 30 feet, and it is liable to sudden changes. On this account the first floor, on which the wheels are placed, is set about 16 feet above the ordinary level of the water in the river, which is above the highest recorded rise, the remaining part of the head being obtained by the use of draft tubes.

It was decided to use two wheels to develop the required 2500 horse power and to couple the shaft of the water wheel to the shafts carrying the stones used for grinding the wood.

It was therefore necessary that the wheels should run at a speed of 225 revolutions per minute. This requirement, as well as the requirements of strength, precluded the use of any of the stock wheels in the market and made a special design necessary.

Under my plans and specifications the wheels were built by James Leffel & Company, of Springfield, Ohio.

The wheel runners are 66 inches in diameter. The bucket rings are made of a special quality of bronze. These rings are fitted to a heavy cast iron center with steel bolts; each ring supplied with twenty-four buckets, with the discharge opposite each other. The wheel runner is fitted substantially with keys to the wheel shaft, which is made of hammered wrought iron, finished diameter through bearings $6\frac{7}{8}$ inches, with a total length from center to

center of couplings of 17 feet. In order to prevent the wheel shaft from shifting endwise, suitable adjustable collar bearings are located on it, immediately on the inside of the elbow.

Surrounding the outside of the wheel runner are wheel cylinders, supplied with twenty gates. These gates are made of cast steel and designed to be as nearly balanced at all points of the gate opening as possible. They are mounted on steel gate bolts attached to wheel cylinders. Each gate is supplied with two side-rack arms, which arms are attached loosely to the two side-rack rings. These rings are mounted on the wheel cylinders, and are operated simultaneously by the movement of the gate shaft connecting to them with roller rings made of cast steel. The gate shaft is made of hammered wrought iron, passing through bronze stuffing boxes in the sides of the cylindrical case. One end of this gate shaft is operated by a suitable lever, with bronze nut, steel screw and hand wheel for same, carried in the heavy frame mounted on one of the elbows.

The work is contained in a cylindrical case 10 feet in diameter by 4 feet wide. The heads are made of heavy cast iron, with $\frac{3}{8}$-inch steel shell solidly riveted to them. On the top of the case is a large air chamber to assist in equalizing any irregularities in the flow of the water to the wheel. This air chamber is supplied with an air pump and glass water gauge, so that it can be cleared properly and filled with air when necessary. The case is also fitted with manholes and plates.

On the side of the case elbows are fitted, which are made of cast iron, being split through the center and bolted together, and where the wheel shaft passes through the elbows are stuffing boxes with bronze glands. Each elbow is fitted with manholes and plates.

On the discharge end of the elbows are fitted draft tubes which are each 18 feet long, made of $\frac{1}{4}$-inch steel thoroughly riveted and calked throughout. These draft tubes are substantially anchored to the foundation walls to prevent breaks or leakage by any movement. The wheel shafts, after passing through the elbows, are carried in heavy flat bearings, each 24 inches long, lined with anti-friction metal, bored to fit the shaft and supplied with ring oiling attachments, with large capacity of oil chambers at each end and on bottom sides of the bearings. The bearings are mounted on heavy cast iron bridge-trees, and are supplied with suitable bolts and adjusting screws, making a distance of 4 feet from the center of the wheel shaft down to the top of the steel beams.

The work is mounted on four heavy 20-inch steel beams, of

suitable strength and proportion for spanning the foundation walls, which are 14 feet 6 inches in the clear.

In 1892 the Niagara Falls Hydraulic Power and Manufacturing Company commenced an enlargement and improvement of its canal. The plan adopted was to widen the original channel to 70 feet and make the new part 14 feet deep. The canal is cut entirely through rock below the water line.

The power for driving the drills on this work was obtained from an air compressor run by water power from the power station and transmitted along the line of the canal in pipes. The excavation was done by dredges and the flow of water through the canal was not interfered with.

This improvement is now completed, and the canal has a capacity of about 3000 cubic feet per second, giving a surplus power, after supplying the old leases, of about 40,000 horse power.

Since this improvement has been completed a new power house has been commenced for the purpose of supplying power for tenants.

For this new plant water will be taken in an open canal from this hydraulic basin to a forebay 30 feet wide and 22 feet deep, which is now being built near to the edge of the high bank. From this forebay penstock pipes built of flange steel, 8 feet in diameter, conduct the water down over the high bank 210 feet to the site of the power house on the sloping bank at the edge of the water in the river below the falls.

The site of the power house was covered with broken and disintegrated rock which had fallen from the bank during ages past, which covered the bed rock to a depth of from 10 to 70 feet.

For the removal of this loose material a Giant or Monitor, as it is termed, was used. This is a machine throwing a stream of water from 4 to 6 inches in diameter, according to the size of the nozzle used, under pressure. It is very largely used in the Western part of the United States for mining purposes.

The water to supply this machine was taken from the canal, and the pressure of 210 feet head fall was sufficient to give a force which readily washed down all the loose material into the river, uncovering a bed of sandstone upon which the power house is built, and from which the material of which it is built was quarried.

The power house building will be 180 feet long by 100 feet wide, and will contain sixteen wheels of about 2000 horse power each. Only one-third of the length of the building is being constructed at present, it being intended to add to it as the demand for power arises.

The wheels in this power house will work under a head of 210 feet, which is the highest head under which water has ever been used for power in the quantity proposed in this plant.

The wheel which has been most used in the United States under high heads is the Pelton wheel, which is an impact wheel running on a horizontal axis. The use of the Pelton wheel was deemed inadvisable in this plant, because on account of the fluctuation of the water in the lower river, which is as much as 30 feet, it was necessary to place the floor of the station on which the generators were to stand about 20 feet above the ordinary water level, and, as it was desired to couple the generators directly to the end of the water wheel shaft, it was necessary to place the water wheels also at this elevation. This necessitated the use of draft tubes in order to obtain the full head available, which is impossible on the Pelton wheel.

It was necessary that the wheels would run at a given speed suited to the speed desired for the generators.

All of these conditions could not be met by any other construction than the turbine wheel, mounted on horizontal axes.

It was decided that water for the wheels should be supplied by a penstock leading from the forebay above described, vertically, about 135 feet to the top of the sloping bank, thence down the slope to the side of the station next to the bank, 8 feet in diameter, connecting with a supply pipe 10 feet in diameter, running horizontally along the center of the tailrace, from which the wheels would draw their water by connections from the bottom of the wheel case to the top of the supply pipe. In this connection, which is 5 feet in diameter, valves are placed so that any wheel can be shut down independently of the others. The wheels standing directly over this trunk discharge the water through draft tubes running down on either side of the supply pipe.

Several reliable builders of water wheels were asked to design wheels from my general plans and specifications, of which the following are the more important points:

"The wheels to be furnished under these specifications shall be horizontal in form, and figured to furnish 1900 horse power, measured on the shaft of the wheel, and to run at a speed of 300 revolutions per minute.

"The head under which these wheels will work will generally be 210 feet, but the wheel shall be figured of sufficient capacity to deliver 1900 effective horse power under a head of 205 feet, and all parts shall be of sufficient strength to stand the pressure due to a head of 220 feet without undue strain.

"The wheels shall be designed to take water directly underneath the bottom of the case at the center, and shall be provided with a supply pipe of such length as shall be specified on drawings hereafter to be furnished, which shall not exceed 2 feet below the periphery of the case.

"The case shall be supported on four 20-inch steel beams weighing 80 pounds per foot and 21 feet 6 inches in length.

"To these beams all the bridge-trees and the case shall be fitted and fastened.

"The beams shall be set such a distance apart and carrying the case so that the center of the shaft shall be at such a height above the top of the beams as shall be specified upon drawings to be hereafter furnished.

"The contractor shall guarantee all parts of the wheel to be of sufficient strength to stand the strain as above specified.

"He shall further guarantee the wheel to furnish 1900 effective horse power, measured on the shaft of the wheel when working under an actual head of 205 feet, and running at a speed of 300 revolutions per minute.

"He shall further guarantee the wheel to show a percentage of useful effect of not less than 78 per cent. at any point between full and three-quarters water under any head from 205 feet to 225 feet, and running at a constant speed of 300 revolutions per minute.

"He shall further guarantee a percentage of useful effect of not less than 60 per cent. under the same conditions from three-quarters to one-half water."

Under these specifications a contract was let to James Leffel & Co., of Springfield, O., for supplying the four wheels to be put in at present. The description of the wheels is as follows:

The wheel runners, in case of three wheels which are to run the generators of the Pittsburg Reduction Company, and which are to run at a speed of 250 revolutions per minute, are 78 inches in diameter; in case of the other wheels, which are to run at 300 revolutions per minute, 66 inches, the size being calculated so that a point in the periphery of the runner will move at a speed equal to about 75 per cent. of the theoretical velocity of water, due to the head under which the wheels are operating.

The rim of the runner is the bucket ring, and is cast solid from gun metal bronze. On this rim are two sets of buckets taking water on face and discharging at each side of the rim. The bucket ring is bolted to the spokes of a cast iron center, the hub of which is keyed to the shaft of hammered iron 20 feet in length.

Surrounding the outside of the runner is a cylinder in which

the gates are fitted. The gates are about 20 per cent. less in number than the buckets. They are hung on steel pins, and open by lifting one edge so that the direction in which the water enters the wheel is nearly tangential to the runner.

Each gate has two arms, which are connected to the rings, by means of which they are opened and closed.

This work is inclosed in a cylindrical case 11 feet in diameter and 4 feet long, which is connected to the penstock by a supply tube 5 feet in diameter.

On the side of this case elbows are fitted, to which the draft tubes are connected. The shaft passes out through these elbows through stuffing boxes. On the inside of these elbows lignum vitæ steps are fastened, against which rings on the shaft work to prevent end motion in the shaft.

To each end of the water wheel shaft will be rigidly coupled a direct current generator, capable of developing 560 kilowatts of electrical energy.

The beams upon which the wheels stand will be extended through underneath the generators, the whole to be fastened together and bolted firmly to the masonry foundations.

It is probable that regulation of speed will be secured by the following described device, though it is not fully decided:

The apparatus for regulating the speed of the wheels consists of a hydraulic piston, which applies its force in either direction to a rack which is connected with a pinion in the gate rigging of the turbine.

The force which operates the hydraulic piston is air, compressed under about fifteen atmospheres.

This compressed air is contained in a cylinder directly under the bed of the machine, and the pressure is maintained by a pump which constitutes part of the machine.

The pressure tank is about one-third full of a fine oil, and the piping is such that oil and never air enters the hydraulic cylinder.

There is a partition in the pressure tank, and one part of the tank is filled with oil and air under the pressure of fifteen atmospheres, and the other part of the tank is a vacuum.

After the oil has expended its force on the horizontal cylinder it is discharged into the vacuum end of the tank, and by the pump transferred into the pressure end. In this way a constant pressure and a constant vacuum are maintained. In other words, the oil circulates under pressure in a closed system without any access to atmospheric pressure.

The machine is provided with a high speed ball governor,

which actuates a balanced piston valve which stands in the circulating system. This valve has a lap 1-64 of an inch, and a motion of that moved one way or another as the speed varies throws the oil under pressure into one end or the other of the hydraulic cylinder, causing the rack to move so as to open or close the gates of the turbine, according as the speed is rising or falling.

The governor has an appliance by which the governing machine is checked before it has carried the gate too far open or shut, thus preventing racing, which has always been the difficulty with most machines devised for regulating the speed of water wheels.

The electric current generated in this power house will be conducted to the top of the high bank by copper conductors, carried up through an inclosed wire tower, and from thence distributed to the various consumers.

DISCUSSION.

MR. BASSETT.—Why is it necessary to place the wheels so far above the water level in the river and use draft tubes?

MR. JOHNSON.—Because of the rise in the river during storms, which is sometimes as much as 30 feet; that is to say, the total variation between the extreme high and the extreme low water in the river below the falls is liable to be as much as 30 feet; that is, the water level is liable to vary as much as 15 feet either way from the ordinary level.

MR. BASSETT.—Why should there be such a rise at the falls when the rise at Buffalo is only about 5 feet during a storm?

MR. JOHNSON.—The narrowness of the river below the falls near the Cantilever Bridge chokes the flow and causes the rise. The rise at Port Day, where the canal intake is, just above the rapids above the falls, is from 5 to 6 feet. The river at that point is probably a mile wide.

MR. T. GUILFORD SMITH.—What is the total amount of power proposed to be developed by the power companies at Niagara Falls by the plans now being carried out?

MR. JOHNSON.—The tunnel already built by the Niagara Power Company has a capacity of about 100,000 horse power. They have the right to draw water from the river to the amount of 200,000 horse power, and I believe contemplate the possibility of constructing another tunnel. The present capacity of the canal of the Niagara Falls Hydraulic Power and Manufacturing Company is about 50,000 horse power, and can readily be increased to 100,000 or 200,000 horse power.

Mr. Smith.—What is the present capacity of your canal?

Mr. Johnson.—About 3000 cubic feet per second. If the canal were to be deepened this could be very materially increased. The canal is capable of development up to 100,000 horse power, or even 200,000 horse power.

Mr. Guthrie.—What is the estimated quantity of water that will be taken from the falls by these two plants when completed?

Mr. Johnson.—The grant to the Niagara Power Company says, "Water sufficient to produce 200,000 effective horse power." This language is about as definite as would be a deed of sufficient land to raise a certain number of bushels of corn annually. I suppose this grant would probably be construed to mean somewhere from 13,000 to 13,500 cubic feet per second.

The Niagara Falls Hydraulic Power and Manufacturing Company is at present using something like 1000 cubic feet per second, and if its plant should be increased to 200,000 horse power would use from 11,000 to 12,000 cubic feet per second.

Mr. Guthrie.—What effect will that have upon the falls?

Mr. Johnson.—The drawing from the river of the extreme quantity mentioned, it is estimated, would reduce the depth of water on the American falls about 3 inches, and on the Canadian falls about 11 inches. It is not likely, however, that this extreme quantity of water will be used for the next one hundred years or so, and, even if it should be, the slight changes in the depth would be immaterial when it is remembered that the difference in the direction of the winds is continually making a difference from day to day of some 3 to 6 feet.

Mr. Smith.—Are there not times now when the rocks in the river above the falls are out of water which at other times are covered?

Mr. Johnson.—Yes, sir; frequently.

Mr. Rogers.—Why did you say Pelton wheels were not adopted for your plant?

Mr. Johnson.—By using them we would lose about 16 feet of the head, as draft tubes cannot be used with Pelton wheels. This is the reason why the use of Pelton wheels was not seriously considered in this plant. I would not be understood to say that the Pelton wheels are necessarily the best for such a plant as this if it were not for the necessity of the use of the draft tube. The Pelton wheel is the only wheel which has been used successfully under extreme heads of, say, 500 to 1500 feet. Under 200 feet head I am not at all sure that the turbine wheel is not as good or better than the Pelton.

A MEMBER.—Will the mills that take water from the canal continue to do so after the new plant is completed, or will they use electricity?

MR. JOHNSON.—They will probably continue to run as they do now. This electric power is intended for supplying new consumers.

A MEMBER.—What is the capacity of the power plant you are now building?

MR. JOHNSON.—7000 horse power at present, with a contemplated increase to 20,000 or 25,000 by an extension of the same station.

A MEMBER.—Where are the wheels being built?

MR. JOHNSON.—By the Jas. Leffel Wheel Company.

MR. MCCULLOH.—Have you any data upon the cost of excavating by the hydraulic excavator you used in preparing the foundation for the new power house?

MR. JOHNSON.—I am not able to state the exact cost at present, as it was all day's work, done by the power company itself.

PAVING BRICK AND BRICK PAVEMENTS.

By H. J. March, Member of the Society.

[Read before the Engineers' Society of Western New York, November 9, 1896.]

HISTORY.

Brick have been in use in one form or another for a great many centuries. It is recorded that in 2247 B.C. the descendants of the sons of Noah said: "Go to! Let us make bricks and burn them thoroughly."

The Tower of Babel was built of well-burned brick. The mud of the Nile was the only material in Egypt suitable for brickmaking.

The plan was to make a bed into which were thrown large quantities of cut straw, mud and water, and this was tramped into pug, removed in lumps and shaped in molds by the hands. The molded clay was sun-dried, not burned, the bricks of Egypt being adobes. Contrasting this mode with that of to-day, it seems very crude indeed. Bricks, burned and unburned, were employed to some extent in the construction of the Great Wall of China, completed in 211 B.C. The credit of first burning bricks in kilns probably belongs to the Romans; but it is hard to fix the time of this improvement. The knowledge of the art of brickmaking has probably at no time become entirely extinct; but with the decline of Roman civilization it gradually expired, and was lost in Western Europe. The Romans made bricks extensively in Germany and in England.

During the reign of Henry VI brick construction was not very general, but under Henry VIII and Elizabeth the brick industry grew extensively. The fourteenth century did not see much brickwork construction, but in the fifteenth brickwork became common.

Up to the seventeenth century bricks made in England were of variable sizes. Charles I, in 1625, regulated the size considerably, and made them nearly uniform. In Holland and other provinces of the Netherlands, where no stone, except of inferior quality, is found, brick have been of universal use from the earliest times, the paving of streets and other public works being done with them. Hard paving bricks were made from a mixture of slime from the Haarlem Meer and sand. The celebrated Dutch Clinkers, or paving brick, were made at Moor from the slime of the River Yessel. In this country the New Haven colony was the earliest settlement in which brickmakers were recorded as a part of the population, and it is probable that in 1650 the first bricks made in this country were

burned by this colony. Brickwork became common here about the eighteenth century. Improvements in modes and machines for making common bricks received but little attention prior to 1840. Very little care was paid to the brick after they came from the kiln, the whole idea being to shape or mold them in some way. Consequently the bricks were light and porous, and absorbed a large amount of water; but modern brick machines have lessened materially these objections. We find bricks were first used for paving in this country about 1870, at Charleston, W. Va. This brick was simply common building brick, burned hard, resting on a board foundation. From this first use of hard-burned common brick for street pavement there has gradually grown the vast paving brick industry, common in our Western States particularly, fostered by the demand for a cheap, as well as a durable, pavement.

CLAY.

Paving brick in general are made from fire clay or shale, or both. The term clay is applied to the hydrous silicates of alumina, and has been produced largely by the decomposition of felspar rocks, caused probably by water disintegrating the binding material. The rocks containing a good proportion of oxide or salts of iron forming red clays, and those having but traces forming white or light clays. Pure clay has been found to be infusible even in the most intense heat, but when mixed with the alkalies or alkaline earths it becomes fusible in proportion to the admixture. Clays possessing a high degree of plasticity are termed long or fat, but when having little plasticity are termed short, meager or lean. In the parlance of the brickyard the first is called "strong clay" and the latter "weak clay." Strong clays absorb considerable water in tempering, and bricks made from these clays shrink materially in drying and burning. On the contrary, weak clays absorb but little water, and do not shrink either in drying or burning.

There are two distinct machines used in brickmaking,—namely, dry clay machines, using clay that has been dried by the sun and wind, and wet clay machines, in which the clay is worked in its moist condition as found in the bank. The stock from the dry clay machines is produced by the employment of molds to shape the clay. This product is more generally used for architectural purposes. The wet clay machine stock is used for engineering purposes, and is produced by forcing the plastic clay through a die in a continuous string, which is afterwards cut into bricks of required size. Bricks made by the former class of machines are far inferior as regards durability to bricks made by the latter machines.

I have read that some years ago in Washington, D. C., they had a costly proof of this fact. The invert of a sewer in which the first-named brick were used was entirely cut out by sand and gravel, and let fall a section of more than 700 feet in length. To confirm this statement I wrote to the Engineer Commissioner at Washington, D. C., and Captain L. H. Beach, assistant in charge of sewers, writes me that "our records show that the only case of sewer failure due to defective invert occurred in 1877, when a section of the North Capitol street sewer, about 245 feet in length, failed because brick invert was washed out. The kind or quality of the brick was not mentioned." However, what I have mentioned may be true in fact.

Analyses show that the best paving brick clays contain about 60 per cent. of silica, 20 per cent. alumina and the remaining 20 per cent. of iron, lime, magnesia, soda, potash and water. Alumina gives elasticity to the brick, although an excess of alumina is liable to produce checking or cracking in the kiln. The iron element should be less than 6 per cent. when necessary to subject a brick to high temperature. Lime is very injurious in a paving brick, and should not be in excess of 3 per cent., as it is changed in burning to caustic lime, which, when exposed to moisture, slacks, and consequently disintegrates the bricks.

The difference between fire clay and shale brick is not clearly defined. Generally speaking, fire clay bricks are of a light color, varying from all shades of yellow to almost white, due to the absence of iron and fluxing elements. They are capable of standing a heat of 2000 to 4000 degrees Fahrenheit. Shale bricks vary in color from a dark brown or red to a light gray, and possess more or less of a tendency to a laminated structure. They also contain about 8 per cent. of iron, which largely determines their color. Fluxes to the amount of about 5 per cent. are also a characteristic of the shale product.

In tests for compressive strength a great many shale brick are found to stand about 5000 pounds more than fire clay brick. This fact alone is not a material argument in their favor if it can be proved that such excessive compressive strength is not necessary for best efficiency, unless there exists correlatively a superior structure.

It would take too long to describe the process of manufacture through its varying degrees of preparing the clay, grinding, screening, tempering, molding, repressing, drying and burning. Suffice it to say that these several degrees in the process of manufacture should be mastered in all their detailed operations by the workmen, so that there would not be the slightest departure in their execution

day by day in order that a uniform product may be obtained. The greatest defect in the paving brick industry of to-day is the lack of uniformity in product from the same manufacturer. If manufacturers could be assured that all their brick could be made equal to the best that they had produced they would be supremely happy, not to speak of the joy that would come to engineers. Different clays demand different treatment, and all demand the closest attention as to operation before and after setting in the kiln in order to be assured of good results. I have recently heard of a new kind of paving brick, composed of common coal ashes and a few chemicals, which require no burning and are ready for use five hours after made. Generally speaking, freedom of method in operation should be accorded the several manufacturers, both for economy and efficiency. The finished products alone should be required to meet the standard of tests.

SIZE AND SHAPE.

Let us look at some of the finished products. They are of varying sizes, shapes and color. Other things being equal, the proper size and shape of paving brick should be determined primarily by the element of commercial usefulness; that is, they should not be so small as to cause an unnecessary large number of joints or to increase materially the time of laying them for pavement or for any other purpose. They should not be so large as to afford but little foothold for horses, although we may be approaching the horseless age. However, when all phases of the question are considered, it seems to me that the proper size for a paving brick is that of the ordinary building brick. Bricks of this size, when unfit for pavers, can then be used for building and other commercial purposes. This available secondary use, obtained by retaining likewise the same shape as building brick, renders them cheaper for each designed purpose.

Not a few brick advocates favor a brick with rounded top edges; others lateral projections and grooves, or a combination of both. However, my experience has been that a brick with rounded top edges presents a more attractive appearance in the pavement. These several features, large size, shape, etc., may have some advantages, but I do not think they are of sufficient importance to warrant their general adoption at the sacrifice of usefulness for other purposes. It is claimed by some manufacturers that a brick of the block form, on account of its large size, cannot be thoroughly and uniformly burned. This claim, in point of fact, I do not think is well grounded, although there is a limit of size. There is no impera-

tive demand for bonding brick together by special patented forms, simply because there is no great strain to be distributed over the impacted material that cannot be accommodated by the ordinary form of brick.

CHECKS AND CRACKS.

There are some brick that are full of checks and cracks, particularly cobweb cracks. These have been caused probably in the drying process, by drying too rapidly; or they may have been hacked in the wind or in a strong draft; or, again, they may contain too much alumina, to which I have already alluded.

END CUT AND SIDE CUT BRICK.

Brick are cut the desired size in two ways,—namely, the end cut and the side cut. The latter is more generally preferred, because when laminations occur in brick, as is the tendency of incomplete clay operations, they are found to be parallel with traffic, and hence less liable to chip. This has always been the belief until recently, when more complete tests by Professor Orton have evidenced the contrary. See *P. and M. Journal,* March, 1897.

REPRESSING.

Many persons claim that a repressed brick is far superior to what is known as the standard or square brick not repressed because it is claimed that repressed brick are rendered more nearly uniform in size and density and present a more attractive appearance. But if by so doing the clay perchance be too dry, the bond is broken and the structure changed; then repressing is undesirable. I am told by a manufacturer that repressed brick are harder to burn, and when burned are apt to be hard on the outside and soft in the center. Professor Orton's tests show that it is of great advantage to repress end cut brick because of condensing laminations, and of great disadvantage to repress side cut brick. See *P. and M. Journal,* March, 1897.

VITRIFIED BRICK.

The chemistry of burning, according to Chase, is at 100 degrees C. the water held in mechanical suspension is driven off. That held in chemical combination is driven off at a little below red heat. At a red heat the carbonates are decomposed, and organic matter is consumed. At a white heat vitrifaction takes place, and from here the kiln is gradually cooled. Professor Baker says: "Vitrified brick are generally very hard, and generally also equally brittle and unfit for a pavement. There may be clays which make the

best paving bricks when burned to vitrifaction, but the writer (Professor Baker) does not remember having seen any such." On the contrary, Mr. C. P. Chase, an engineer of Iowa, in speaking of defective brick in a pavement one year old, says: "There were not a large number, but sufficient to show that brick, no matter how hard or compact they are, will not do for paving unless evenly burned and vitrified." I have in mind one vitrified brick product which I have tested, the results of which are in accordance with Professor Baker's idea. It absorbed very little water, about one-quarter of one per cent.; was so very hard and brittle that it flaked off in chips when in the rattler, rendering its abrasion percentage very high. It had long been my impression that this brick was burned too hard; that is, too highly vitrified. Yet later tests show it to be very satisfactory. In correspondence lately with the manufacturer of this brick I found that the mixing had been decidedly more thorough, and that the time of burning had been reduced from eleven days to nine days, which undoubtedly accounted for better results. There may be clays that demand vitrifaction for best efficiency, but this is not true of all clays.

SALT GLAZED BRICK.

Does salt glazing improve paving brick? Many claim that it is done to cover up structural defects. Salt glazing, however, can only be applied to hard-burned material. If there be any great injury done by its use it is that caused by the natural dampness of the salt being imparted to the kiln when at a high temperature, thus suddenly cooling the bricks, thereby having a tendency to check or crack them. Salt glazed bricks would naturally absorb less water than others. But this is no great advantage over other bricks if their absorption is not excessive; that is, above what has been deemed reasonable, and is in harmony with other desirable qualities. Salt glazed brick, presenting a glazed surface as they do, are more slippery than others. Several manufacturers have informed me that they did not believe in salt glazing paving brick. I have herewith tabulated some information that may be of interest, sent me at my request by several manufacturers of paving brick.

STANDARD TESTS.

Let us now examine the structure further by a standard of tests. I do not think there is a more opportune time than this to emphasize the necessity for a standard of tests that may be uniformly adopted in every detailed operation, so that we may not only know the comparative value of different paving brick, but also

the probable durability of the same under such and such extent of traffic with given modes of construction. Hundreds of tests of paving brick have been made that are only of local value, because of the varying conditions governing them. We note with pleasure the progress in this line of the committee appointed by the National Brick Association for the purpose of outlining a standard of tests for paving brick, based on careful experiments. The tests that have been adopted by those who have given the matter special study are:

1. Lime test.
2. Specific gravity test.
3. Transverse test.
4. Crushing test.
5. Absorption test.
6. Abrasion test.

In the annexed table will be found these several tests as conducted by different authorities.

The necessity of tests to determine what kind of brick shall be used is conceded by almost all. There seems to be the greatest difference of opinion concerning the abrasion test. One writer deprecates the use of Quincy granite as employed by another in the abrasion test for comparison, because of the lack of uniform conditions. This is quite right in point of principle; namely, that no comparison of results should be made unless governed absolutely by the same conditions. Theories and arguments work out very nicely when based on given conditions. But let us first be sure that our conditions are given, are absolutely certain. For instance, the complete identification of the brick throughout all the tests, the correct weights, the use of similarly shaped scrap iron, or foundry shot of certain number of pieces, and of certain weight, and the same number of brick each time, the time and speed of running the same rattler,—all of these requirements make up uniform given conditions. These conditions of uniform tests can best be obtained by the municipality possessing a testing laboratory of its own, where materials and detailed operations of testing may be under the immediate care of the engineer in charge.

Of late there has been a tendency on the part of some to discard the absorption test, because it is claimed that any brick that will stand the rattler test will stand the absorption test. I think that the abandonment of this test would be an unwise procedure, for every test has its value which is of no little importance.

In reference to the absorption test I have found that out of ten different kinds of brick, there being two of each, in one set of ten

REPORTS FROM MANUFACTURERS.

ENGINEERS' SOCIETY OF WESTERN NEW YORK — H. J. MARCH, M.S., C.E.

	Name of Brick and Where Made.	Manufacturer.	Are your Bricks: Fire Clay Only?	Are your Bricks: Shale Only?	Are your Bricks: Mixture?	Price, at Works, per 1000 of — Building Size: Not Repressed.	Building Size: Repressed.	Block Form: Not Repressed.	Block Form: Repressed.	Do you use: Dry Clay or Wet Clay Machines?	Do you use: Up Draft or Down Draft Kilns?	Do you prefer Paving Bricks to be: Vitrified?	Square Edge?	Repressed?	Building Size?	Block Form?	Salt Glazed?	Capacity per Day.
1	B.	....			Yes.	$	$	$	$	Both.	Down D'ft.	Yes.	No.	No.	Yes.	No.	No.	20,000
2	B. R.	....	Two Kinds of Fire Clay.	10% Shale and Fire Clay.		8.00	8.50			Wet Clay.	Down D'ft.	Yes.	Yes.	No.	Yes.		No.	150,000
3	C.	....	No.	Yes.	No.	6.50	7.50	9.00	10.00	Wet.	Down.	No particular Choice, are Selling Mostly Block.					No.	150,000
4	E.	....		Shale.	Shale with 20% Com. Clay.	9.00	10.00	11.00	12.00	Direct from the Bank, Tempered to Stiff Clay.	Down D'ft.	Yes.	Beveled.	Yes.		Block.	No.	25,000
5	F.	....		Shale.			8.75			Wet.	Both Up and Down in Same Kiln.	Yes.	Yes.	Yes.		No.	No.	35,000
6	K.	....	For Fire Brick.	For Street Brick.			Yes.		Yes. 10.00	Stiff Mud.	Down.	Yes.	No.	Yes.	No.	Yes.	No.	30.000
7	M.	....	Both Fire Clay and Shale.		No.	7.00	8.00	11.50	12.00	Wet.	Down.	Yes.	No.	Yes.	No.	Yes.	No.	165,000
8	Pk.	....	Yes.			9.00	10.00	15.00	16.50	Wet Clay.	Down.	Yes.	Yes.		Yes.		No.	250,000
9	Pn.	....		Yes.			8.00		10.00	Wet Clay.	Down.	Yes.		Yes.	2½ x 4 x 8.	3¼ x 4 x 8.	Never.	300,000
10	S.	....			Alluvial Clay.	10.00		Large 12.00		Wet.	Down.	Yes.	Yes.	No.	Yes.	No.	No.	70,000
11	Tn.	....			Yes.	15.00	16.00			Stiff Mud.	Up Draft.		Yes.	No.			No.	20,000
	Average..............................					$9.22,	$9.59.	$11.70.	$11.75.	Majority Wet Clay.	Majority Down D'ft.	Maj. Yes.	Maj. Yes.	Maj. Yes.	Maj. Yes.		All No.	110,455 Average.

the bricks were broken in halves, and in the other set the top, bottom and narrow end faces were removed for about one-half inch; that in this latter set the absorption percentage was higher in eight out of ten bricks than in the former set. The absorption percentage upon similar whole bricks was less than either, showing that the interior of the brick was more porous than the exterior, and also indicating, since this was with forty-eight hours' immersion, that twenty-four hours' immersion would have been too short a time for this lot of bricks, and I think in general for all brick, although, of course, the greater amount of absorption would occur in the first few hours.

I do not think there is any definite dependency of abrasion on absorption, save in maximum and minimum absorption there is generally the greatest abrasion; in the one case the bricks being too porous and soft as to wear away gradually, and in the other case being so hard as to flake off in considerable quantities. A study of the annexed graphic table of tests in which Medina sandstone was also tested for comparison will prove the foregoing assertion. In reference to abrasion, the difficulties encountered by the adoption of a standard of tests when departing from what has been the custom are at once apparent when one compares new results with former results, for there has been much of indefiniteness in tests everywhere. However, the way is to make the radical change if necessary when a standard test has been developed, and then all results may be justly compared. I do not think it advisable to use cast iron bricks or pieces of pig iron in the tumbling barrel, principally because a use of them causes a severity of results unwarranted and unfair when actual service in the pavement is considered. Again, tests are not so comparative as we think when under such conditions. Should abrasion percentages be compared one with the other, even in the same tests, where large iron blocks or pieces of pig iron are used when the chances exist of one brick being unduly pounded more than its neighbor? To show the effect of speed of revolution on results in practically the same sized and shaped barrel under practically the same conditions, except that of speed, the number of revolutions being practically the same, I have arranged these tests, made as follows, upon the same kind of brick:

RATTLER, THREE FEET LONG BY TWO FEET DIAMETER.

	Speed, 30 to 35 revolutions per minute.	Speed, 52 to 56 revolutions per minute.
	ABRASION, PER CENT. LOSS.	
First Tumbling	13.88 per cent.	7.28 per cent.
Second Tumbling, alone	4.66 per cent.	2.26 per cent.
Total of first and second Tumblings	18.00 per cent.	9 46 per cent.

It will be observed that with nearly double the speed there was only about half the loss, showing that with the higher speed the barrel went so fast as to carry the bricks with it, and in consequence there was less abrasion. Some one has suggested that the circumference of the tumbling barrel should be composed of the brick to be tested, laid close together, as in the pavement, and then subjected to the abrasion wear of scrap iron, etc. This idea has considerable merit in it, although it takes into consideration principally the grinding effect, necessitating a large number of rattler revolutions to get material results. In formulating standard tests it should be borne in mind that the object of tests should be to find the faults of a brick; that is, if it is porous, to what extent; or if it be brittle, to what extent, etc. An immersion of forty-eight hours is generally admitted to be sufficiently long to determine the absorptive value of a brick. Abrasion tests, in accord with the conclusions from experiments by Harrington and others, seem to approach very nearly to what is desired for a standard of tests in this line. I refer to these tests specially because most attention and importance have been given them.

PAVEMENT FOUNDATIONS.

Having now examined paving brick, let us look for a few minutes at the subject of pavements in general and their foundations, confining the discussion more particularly to brick pavements. There are a few primary elements essential to a good pavement, as mentioned by General Gilmore:

1. That it shall be smooth and hard, in order to promote easy draft.

2. That it shall give a firm and secure foothold, and not become slippery from use.

3. That it shall be easily cleaned, and shall not absorb and retain surface liquids, but discharge them quickly into the gutters and catch basins.

4. That it shall be noiseless and as free from dust and mud as possible.

5. That it should be readily taken up and repaired.

6. The roadway surface must be constructed of durable material.

These well-recognized requirements should be borne in mind when judging the efficiency of any pavement. The nature of pavements and their foundations in different cities is largely determined by the available material immediately adjacent to the localities, as the transportation of foreign material from great distances is quite

a large item in the first cost, and more or less so consequently in cost of maintenance.

CHOICE OF A PAVEMENT.

The choice of a pavement, after the above requirements have been considered, is dependent upon local conditions of grade, cost, etc., the popularity of home industries and, unfortunately, in some cities upon the ascendency of one political party or another. The relative rank of merit of different pavements, compiled from experiments and facts of actual service, is shown in the annexed tables.

It will be observed that brick stands in the front ranks, and surpasses asphalt in a majority of the requirements.

There are now about 200 miles of asphalt pavement alone in Buffalo, which amount represents about $10,000,000. Estimating brick at 30 cents a square yard less than asphalt, if it had been chosen by the people its use would have saved $1,000,000 in first cost, which at 5 per cent. interest represents $50,000 per annum. Supposing the cost of maintenance and durability the same, the question is, are the blessings of asphalt pavements so far superior to those of brick pavements to the amount of $50,000 every year? This suggestion, however, must be modified to this extent,—namely, that indefiniteness as to the efficiency of paving brick has in the past precluded its use. This indefiniteness is not so pronounced to-day as formerly, when the efficiency of asphalt was also questioned.

In New York City there is no great amount of brick pavement, and I find these remarks in the *Paving and Municipal Engineering Journal* for October, 1895: "In New York they have ten or more streets paved with asphalt where the grade varies from 2.5 to 6 per cent. One of these streets, with a 6 per cent. grade, was used in preference to parallel streets of less grades that were paved with blocks. Also traffic has deserted Ninety-third street, paved with granite, for an asphaltic pavement with a 6 per cent. grade in Ninety-fourth street. The granite pavement of Fifth avenue, between Thirty-fourth and Thirty-sixth streets, with 4.87 per cent. grade, has to be sanded for safety." In Syracuse I find James street has a grade of 7.3 per cent., and in Rochester Spring street has a grade of 5 per cent. and Clifton street 4.5 per cent. An investigating committee when visiting these cities was informed there was no difficulty in driving over the above-mentioned streets. In Buffalo I think the steepest asphalt grade is one of 5.10 per cent. on Utica street, from Main street easterly. Delaware avenue, from Forest avenue to the creek, has a grade of 4.40 per cent. Church street, from Pearl to Franklin, has a grade of 3.11 per cent.

RELATIVE MERITS OF PAVEMENTS.

From C. P. CHASE.

	Durability Under Traffic.	COST.	Action of Elements.	Noise and Dust.	REPAIRS.	Service on Grades.	HEALTH.
1	Granite.	Brick.	Brick.	Asphaltum.	Brick.	Granite.	Asphaltum.
2	Brick.	Wood.	Granite.	Brick.	Granite.	Brick.	Granite, Brick } equal
3	Asphaltum.	Sandstones.	Sandstones.	Wood.	Sandstones.	Sandstones.	
4	Sandstones.	Asphaltum.	Asphaltum.	Granite.	Asphaltum.	Wood.	Sandstones.
5	Wood.	Granite.	Wood.	Sandstones.	Wood.	Asphaltum.	Wood.

COMPARATIVE $\left\{\begin{matrix}\text{EASE}\\ \text{COST}\end{matrix}\right\}$ OF TRACTION ON DIFFERENT PAVEMENTS.

RUDOLPH HERING'S ESTIMATE.

Iron Rails	1	horse.	Good Macadam	8	horse.
Sheet Asphalt	1⅔	"	Cobblestones.	7 to 13	"
Brick	2¼ to 2¾	"	Ordinary Earth	20	"
Granite Blocks	3⅓ to 5	"	Sandy Earth	40	"
Wood	5 to 6	"			

COMPARATIVE MERITS OF PAVING MATERIALS.

AS USED IN CHICAGO.

Classified by D. W. Mead.

Relative Order of Merit.	First Cost.	Cost of Maintenance.	Facility of Repair.	Durability.	Freedom from			Absorption.	Foothold for Horses.	Ease of Traction.
					Noise.	Dust.	Decay.			
1	C. S.	B.	M.	B.	M.	A.	B.	A.	C. S.	A.
2	C. B.	G.	B.	G.	C. B.	B.	G.	B.	G.	B.
3	M.	C. S.	G.	C. S.	A.	G.	C. S.	G.	M.	C. B.
4	B.	A.	C. S.	A.	B.	C. B.	M.	C. S.	B.	M.
5	A.	C. B.	C. B.	C. B.	G.	C. S.	A.	M.	C. B.	G.
6	G.	M.	A.*	M.	C. S.	M.	C. B.	C. B.	A.	C. S.

*This, I think, is improperly placed last, as recent modes of repair have decidedly lessened time and expense of its repair.—H. J. M.

NOTE: A.—Asphalt. B.—Brick. C. B.—Cedar Block. C. S.—Cobblestone. M.—Macadam. G.—Granite.

Delaware avenue, from North street southerly, has a grade of 2.83 per cent. In Buffalo we have endeavored to avoid as far as possible making grades of asphalt pavements greater than 3 per cent. Some asphalt pavements of 4 to 7 per cent. grades may not be difficult to travel over if the weather is warm and high temperature has softened the asphalt so as to afford a foothold for horses, but in winter and with rainy, freezing weather I have seen drivers forsake an asphalt of 0.4 per cent. grade for a stone pavement. A brick pavement, because it will not wear smooth or polish, as do some stone pavements, will permit the use of any grade that may be desired.

UNDERGROUND IMPROVEMENTS.

The first consideration for a good pavement is the question of assurance that all main sewer, water, gas and other pipes or conduits and lateral house connections are in good condition as regards quality and trench settlement. Too much attention cannot be given to these underground improvements. The second important step is that all pavements, of whatever nature, should be laid in good weather and under all other favorable conditions as may be obtained. The street should be graded two feet wider than width of paving to proper grades, and sub-grades conformable to proposed crown of finished pavement. Soft or spongy places, not affording a firm foundation, should be dug out and refilled with good earth, broken stone or other equally good material, well rammed. The sub-grade should be thoroughly rolled with steam roller not less than five tons weight. No ploughing for rough grading should be done within 3 inches of the sub-grade.

DRAIN TILE.

Unless a sandy or gravel material exists, as the street grading progresses, a 4-inch porous drain tile, with open joints, to be covered with broken stone, should be laid on each side of the street back of the curb, in straight line and true grade, about 24 to 30 inches from top of curb to top of tile, so that water may be prevented from reaching the foundation of pavement. If the street has a heavy descending grade, then the use of drain tile is unnecessary. I find that a great many cities do not use drain tile, but we find in Buffalo that its use is of great advantage to the life of a pavement.

CURB.

The curb, which should be good, hard stone not less than 4 inches wide and 18 inches deep (preferably 6 inches wide and 12

inches deep), and not less than 36 inches long, dressed evenly, should be set in concrete or sand, backed by 6 to 8 inches of same material, care being exercised to set it in true line and grade. At the end of each curb, when set in sand, should be placed a small stone at the base, to prevent curb from being forced out of line. Upon the finished sub-grade shall be placed the foundation course of prescribed material. An examination of the table of comparative construction and cost and efficiency of brick pavements in various cities,—fifty-five in number,—which I have compiled from information sent me by several city engineers, will reveal the customs employed for a foundation course, as well as many other items of interest in pavement construction.

FOUNDATION COURSE.

Some use sand, others gravel; others furnace slag, others an under course of brick laid flat; others broken stone, and others concrete of varying thickness, dependent upon traffic. A concrete base has been generally recognized as the only permanent base. Its use may be quite desirable and altogether wise in the case of wet, spongy land that requires a well-bonded bed over which may be distributed heavy loads that may come upon it, to relieve the immediate local effect; but for sandy gravel soils and those of stiff clay, and where traffic is not extremely heavy, a concrete base does not appeal as the most economic and efficient one. There is quite a difference in broken stone, say at $1.30 a cubic yard, and concrete at $3.50 a cubic yard. Some of the best pavements in Buffalo have a 6-inch to 8-inch broken stone base. Again, concrete is not entirely stable, for its movements have caused much disturbance and no little expense to restore to the rightful place where the upheavals and cracks in asphalt and brick pavements particularly have been experienced.

From experiments in England by Geo. R. Strachan, A. M. Inst. C. E., in which a strip of concrete 6 to 1 ballast, 52 feet long, 12 inches wide and 3 inches thick was laid on sand to allow freedom of movement under a shed with open front, so situated that the sun did not touch it, and another strip 26 feet long, same width and thickness, 3 to 1 pebbles, and a third of the same dimensions, 3 to 1 sand, were also laid under the same conditions. The only movements that he discerned at the end of the month was a slight contraction in length in all the samples. He further says "that the uniform experience of concrete under asphalt is that cracks occur which would tend to show that contraction, not expansion, was the rule." These cracks in asphalt are not wholly due to the concrete

movement, as here in Buffalo, where some experimenting with asphalt has been done, cracks are so numerous that it would be absurd to ascribe the cause to movement of the concrete, the nature of the asphalt and its manipulations being responsible for such effects. Where the expansion of concrete has been experienced it has been attributed to the action of temperature. Curbing that has on one side asphaltic sidewalk and on the other asphalt roadway has been forced out of line toward the center of the street by the expansion of the concrete pushing respectively the top one way and the bottom of the curb the other. In our city of Buffalo we have had no little experience with concrete raising up asphalt pavements, particularly as though a root of a tree had grown underneath.

These effects have not been more generally experienced because mastic asphalt, being elastic, and binder coating, when used, have regulated more or less the movements of the concrete. Although Mr. Malo, the French authority on asphalt pavements, states that the cracking of asphalt pavements is largely due to the use of oils in fluxing and softening the mixtures, and deprecates the use of petroleum or other similar oils for such purposes, many engineers believe that it is due to the laying of asphalt pavements late in the fall and subject to variable weather, and, second, to not removing all moisture from the concrete before the asphalt is laid.

The expansion of concrete, I think, as well as the expansion of brick and the cement filling, has been to some degree the cause of the complaint that has come from cities in reference to the rumbling noise and cracking of brick pavements. The concrete course, as well as the brick course, has arched or shoved up, leaving hollow spaces that cause the rumbling noise, intensified, of course, by the very nature of brick itself.

CUSHION COURSE.

On top of the foundation course for brick pavements a sand cushion is generally placed. In different cities this ranges from $\frac{1}{2}$ inch to 2 inches in thickness. Where the top surface of the concrete is left rather rough I think a 2-inch cushion should be employed to take up in some degree the movements of the concrete and to offset inequalities of brick. In reference to the efficiency of a sand cushion, it certainly is not perfect, especially with a broken stone base, as in some cases it has worked down between the pieces of stone; and because of this one writer deprecates the use of a broken stone base. A desirable cushion would be one of an elastic nature. Sand does not meet this requirement, and yet it seems to be the only practicable cushion.

SELECTION OF BRICK BY COLOR.

For the selection of brick to be used in the pavement there seems to be no definite guide. The kind of fuel used in burning will affect the color, not to speak of the constituent elements of the brick itself. I have made tests of brick where the varying colors of the same product were particularly noted, and no special difference in absorption and abrasion was observed except in extremes. Very dark-colored brick are generally overburned, and, being too hard, are liable to chip off in fragments, while pale, very light-colored brick, being underburned, are not as tough as others. These conclusions are operative upon different-colored brick of the same product, and not upon different products. Generally speaking, the medium-colored brick of any product are the toughest and most durable. Again, that kind of brick is best for paving purposes which when broken reveals a close, homogeneous structure of uniform color, the break being a clean, sharp one.

After the selected brick have been laid with proper crown (which should be parallel with the crown of foundation course and roadbed), and at right angles to the curbs, breaking joints evenly, they should be rolled with a steam roller and all cracked or broken brick replaced by good, whole brick. In reference to the crown of a brick or stone pavement, it is advantageous that it should be lower than the curb grade, so that in the future, after the brick pavement has served its time, it could be surfaced with asphalt if competition with brick pavements should so lower the price of that material that its use would be cheaper than to supply new brick where needed.

FILLING OF JOINTS.

The question of filling joints now presents itself. Some cities have experienced no little trouble in the use particularly of neat cement, and also of a composition for joints. Sand filling is employed in some cities, but the liability of water percolating through the joints and causing trouble has undoubtedly limited its use. However, there has been no special complaint from cities where it has been used that can be traced definitely to this cause. Coal-tar pitch and asphaltum pitch have been used also for filling of joints. The joints of brick pavements laid in Buffalo in 1892 were filled with pitch; but this was abandoned in 1893, cement grout being used since then. The pitch under high temperature softened, and consequently was more or less of a nuisance to passing vehicles.

In Newark, N. J., fire-clay brick were laid in December, 1895, at a temperature below freezing point, cement grout being used

with salt to fill joints. The brick raised, due to supposed expansion of the brick, and resulted in more or less rumbling noise when vehicles passed over. At the same place a brick pavement laid in warm weather, the joints being filled with Portland cement, the rumbling noise has also been experienced, but not to such a large extent as that from pavement laid in cold weather. The Newark authorities are thinking of abandoning the use of cement filling for pitch mastic. Experiments are now in progress there with a combination of both; that is, spaces for 15 feet at intervals across the full width of pavement and for one inch along the curb being filled with a paving mastic, the remaining space being filled with cement grout in the hopes of counteracting the expansive power of the cement.

In Cortland, N. Y., where pitch and cement were both employed, the cement in setting within three days forced the pitch out of the joints. This cement had been tested previously for expansion. After the cement had set the expansion seemed to cease.

In Brooklyn, N. Y., on the McDonough street pavement, where they were troubled by a rumbling noise, the bricks having arched up, a 15-ton steam roller was used in the hopes of breaking the joints. Then a brick or two along the curb was taken out, but even this was of no avail. The theory is that when work was in progress the temperature fell 10 to 15 degrees and froze the sand and concrete. I think that it has now about been decided to remove the brick, so great has been the complaint against its rumbling noise, and lay asphalt on the concrete foundation. This step, if it be taken, will be greeted with joy by asphalt advocates. The above theory, however, as to the cause of such disturbance is contradicted by the experiences in Newark, N. J., to which I have alluded.

On South Sixth street, Terre Haute, Ind., a pavement of Canton brick laid about five years ago gave trouble by rising up in several places. Its construction extended into the winter, and was completed early the following spring. The brick were laid close on broken stone foundation on 2-inch cushion of sand, the joints being filled with Murphy grout.

In Easton, Pa., on account of an 8 per cent. grade, the joints near the gutter of a brick pavement were filled with cement grout for a width of (2 feet in report of city engineer of Easton) 4 feet from the curb, the remaining part being a sand filling. This resulted in a ridge of one-half to three-fourths of an inch in height along the division line between the cement grout joints and the sand joints.

In Wilmington, Del., where they were troubled with a rumbling noise, a strip in the center, 100 feet long and 18 inches wide, was removed, but this afforded no relief.

In Buffalo we have not been troubled seriously by any such bad effects. Dart street, paved in October, 1892, with pitch filling in joints, the brick laid close on concrete base, has one place where there is a rise of about 4 inches for three-fourths of the width of pavement. This is probably due to concrete expansion. Also in 1892 Oakdale place, with cement joints, laid by *private parties,* has bulged up in three or four places to a very small extent. The general condition of the street is good, although I understand a common cement was used for filling joints.

Penfield street, paved in May, 1893, cement joints, has some longitudinal cracks, due in this case probably to water getting under pavement from frozen water pipes, as well as to cement expansion.

Roos alley, paved in October, 1894, has some brick cracked longitudinally in a few places and depressed where repaired below general surface, caused probably by gutter in the center and cement expansion and concrete movement, and also trench settlement.

Laurel street, paved in 1895 and 1896, cement joints, laid by *private parties,* has some small longitudinal cracks, probably due to cement expansion.

Ada place, paved by *private parties* in the fall of 1894 and spring of 1895 with an American Portland cement composition, in the proportion of one of cement to six of gravel, has now about eighteen cross cracks and two or three longitudinal cracks. These, however, are no discredit to this particular cement, for I believe it to be of high quality, and I understand its expansive power is very slight. A defective sub-soil, together with whatever little expansive power the cement might possess when provoked by the elements, would be responsible for the above effects.

The annexed table of brick pavements in Buffalo gives special information concerning length, yardage, cost, etc.

From the foregoing instances we have seen that trouble has been experienced from brick pavements of fire-clay and also shale structure, not only on a concrete base, but also on a broken stone base, and where neat cement and also cement grout and pitch have been used for the filling of joints. Brick pavements laid in warm weather have given forth a rumbling noise, although not to such a great extent as those laid in cold weather. Cement grout, where used in Buffalo, as in most other cities, has been proportioned 1 to 1, and as used thusly one barrel of English or German Portland cement covers about 40 to 50 square yards, at an average cost of 13

cents a square yard for sand, cement and labor, the amount covered depending largely on the size of brick used. The expansive power of cement when used should be little or none, as therein is the disadvantage of its use. Coal tar and asphalt fillers have the disadvantage of softening up in warm weather and running off from the brick, particularly from the center to the gutters, leaving the edges of the brick exposed to immediate abrasion. Sand as a filler, as well as paving mastic, are considered detrimental to the life of a brick pavement because also of exposing the edges of the brick.

The combination of cement grout and paving mastic has not been sufficiently long in use to judge of its efficiency. What is known as Murphy's grout has been used for filling joints in some cities with considerable success, at an average cost of 16 cents a square yard. It is chiefly composed of iron slag and carbonate of lime, clean, sharp sand being added in proper proportion when used on the street. This grout is very hard, and consequently protects the edges of the brick; but does not accommodate itself, as far as I can learn, any better than other fillings to brick and cement concrete expansion. When a filling is harder than the brick the expansive power of the brick and cement tends to crack and upheave the brick. When a filling is softer it wears away, leaving the edges of the brick exposed to wear. What is needed is a hard, elastic filling that will accommodate itself to brick and cement expansion and concrete movement, and which will not soften materially under increasing temperature.

DURABILITY OF BRICK PAVEMENTS.

As to the durability of brick pavements one engineer put their life at ten years; another said in 1891 that many were in good condition that had been down fifteen years, and several over eighteen years old were giving satisfaction.

Prof. Ira O. Baker, in his pamphlet on brick pavements, gives considerable information, based on experiments, as to their durability. In Buffalo, for instance, on Main street, near Swan street, pavement width 56, he estimates that with a total daily tonnage of 2613, or 0.83 ton per vehicle, making a tonnage of 47 per foot of width, that 100 per cent. of sample brick No. 6, the best in the test, would wear away in 226 years, and sample No. 10 in 25 years.

And in New York City, on Broadway, near Pine, pavement width 40 feet, with a total tonnage of 10,905, being 1.39 per vehicle, making 273 tons per foot of width, sample No. 6 would lose 100 per cent. in thirty-eight years and sample No. 10 in four years. Of course, this durability considers the effect of traffic only, which,

however, is the most important item. Again, a pavement would not be of practical use during this period of 100 per cent. wear unless all brick could be worn down equally at the same time, which would be impossible. Experience has proved that a brick pavement shows more wear due to the abrasion of the edges in the first year than it does in the next six years. From my own tests of abrasion as indicative of durability, I have found the best paving brick equal to ordinary Medina sandstone. The best brick in the tests by Professor Baker was found equal to Quincy granite.

So far I have endeavored to present a fair, impartial and just consideration of the question of paving brick and the construction of brick pavements as now in progress in various cities. I have avoided as far as possible laying stress upon any particular merit or merits that a brick pavement may possess.

But let us look for a few minutes at some of the advantages claimed for brick pavements. They have been tersely enumerated by W. P. Judson, C. E., as follows:

1. Less first cost than sheet asphalt, which is its only competitor.

2. Less ultimate cost, as few repairs are needed if good brick are used.

3. Ease of construction and repair.

4. Ease of traction and of cleaning, and freedom from dust and mud.

In reference to the first advantage stated, it is conceded by nearly all that brick and asphalt are the great rival pavements. The less first cost is conceded by asphalt advocates.

In regard to the second advantage, less ultimate cost, it is claimed by asphalt advocates that owing to the short life of brick, its brittle and friable nature when subjected to traffic, makes it more expensive ultimately. Some paving brick that have been manufactured have undoubtedly warranted this conclusion, but such brick are far from representative of the character of paving brick in general.

The third advantage of brick—namely, ease of construction and repair—is self-evident, although it must be admitted that asphalt is now repaired by the aid of modern improvements with considerable more ease than formerly.

For ease of traction on the general run of grades asphalt is superior, as well as in cost of traction. I beg to differ with Mr. Judson also in regard to the ease of cleaning, although in street cleaning contracts brick is classed with asphalt. Again, for better freedom from dust and mud, asphalt ranks foremost. But this is

not a decided advantage, for there is just so much dust and mud from adjoining unpaved streets, etc., which must be distributed somewheres, and, if not upon the asphalt pavement, the dust is blown into abutting houses. Whereas with brick pavements, if the joints are a defective element in them, then these joints would receive the dust and dirt, which ought to be frequently and regularly collected by the street cleaning department.

In point of noiselessness, which Mr. Judson does not mention, some brick pavements as have been constructed are far inferior, and in general they produce more noise than asphalt. I will also add that brick is not materially affected by moisture or fire, as is asphalt, and therefore brick is superior in these respects.

In conclusion, it is not wise, nor is it just, to determine the efficiency of any pavement by casual impressions, such as comfort of riding, pleasing appearance, etc., for there are many considerations, as we have seen, besides these items already mentioned that should determine the efficiency of a pavement.

If I have prompted you to think with favor of paving brick, from the clay bed through their development of manufacture to a material of engineering usefulness in affording a cheap and durable pavement, when properly laid, for hundreds of cities that through their use only can enjoy the blessings which come from well-paved streets, I shall have accomplished a great deal in writing this paper.

DISCUSSION.

Mr. Ricker.—I would like to ask Mr. March if he is familiar with the brick pavement on the principal street connecting Dunkirk with Fredonia?

Mr. March.—I have information from Dunkirk in the list of cities in reference to foundation course, etc.

Mr. Ricker.—I have had very little experience with pavements, but this is a particularly disagreeable and noisy pavement; riding over it is exceedingly disagreeable on account of the noise.

Mr. March.—That seems to be the great trouble in a brick pavement. It is so sensitive when riding over it that vehicles produce a rumbling noise.

Mr. Mann.—I can answer in part. In some of the streets in Dunkirk they laid water and gas pipes and sewer lines just prior to laying the pavement, and undoubtedly the earth has settled away under the concrete, consequently we hear the rumbling noise along the line of the trenches; the concrete holds the pavement up, and it is hollow underneath. There were transverse cracks across the street. What caused this transverse cracking nobody knew.

Mr. Guthrie.—In Chicago there was a discussion on this

point with reference to Brooklyn, Newark and Syracuse also. Some of this rumbling sound is caused by hollow places, the earth settled away and the sand cushion being washed away through expansion of the concrete.

Mr. March touched upon the question of the uniformity of brickmaking; I do not believe we have uniform brickmakers. It is necessary to see that they are more uniform in their making of brick for paving, as I think if the same method of making is used by all makers good results may be reached and certain benefits got by standardizing the tests.

As to the disagreeableness of riding over brick pavements, it seems to me so many joints cannot but make riding in light buggies disagreeable in consequence of striking so many joints.

Mr. Green.—What material has been selected so far as a standard for hardness?

Mr. March.—Professor Wheeler has a formula in which he uses H. for hardness in the mineralogist's scale, brick value 6-½.

Mr. Green.—What material is used as a standard, as I understand the paving brick is tested by a grinding machine which is simply an emery wheel, taking a brick of some standard material and grinding the brick for hardness?

Mr. March.—Granite. An engineer of Peoria, in contradicting Professor Baker relative to the use of Quincy granite, said he had some granite he had tried to have cut down to a regular-sized dimensioned cube, but he found it was almost impossible to get it cut down to the required size and shape. However, Professor Baker uses Quincy granite for comparison, because, granite pavement being the hardest known pavement, any brick that would be equal to that in comparison is suitable for pavement.

Mr. Green.—Granite varies so much in composition and amount and size of the materials which compose it, and in the amount of quartz and other material. Though granite is used in pavements, it would not be used for a comparison for cements.

Mr. March.—Here in Buffalo we do not use granite, but Medina sandstone, cut down to the same size as the brick, is put in the same barrel with the brick. Our desire is to get a comparison between the brick and sandstone.

Mr. Green.—That brings up the same question, which sandstone?

Mr. March.—Gray and red mixed. Gray sandstone is the hardest; it has proved to be in tests.

Mr. Green.—One standard of materials for hardness is quartz, but granite is a conglomerate of very different substances, and I do not see how that can be used as a base or standard.

Mr. Ricker.—Do you have very much trouble with pavements on account of the foundation?

Mr. Mann.—Bad underground work will ruin any pavement.

Mr. March.—This has been found to have been the ruin of parts of pavements.

Mr. Ricker.—I remember when I was a boy in England that when paving one street they must have gone down five or six feet for the foundation for a block pavement of some stone similar to Quincy granite.

Mr. March.—In laying some pavements we have gone down four or five feet.

Mr. Norton.—I have seen some places where it was necessary to go that depth. The future importance of paving brick is a question resting both with the engineer and with the manufacturer. It would be well to have some uniform standard and uniformity of test which the makers may be prepared to meet; after the engineer has done that, his scope is over. Investigation necessarily must be founded on a standard. This we have found in brick pavements within the last few years.

Niagara Falls has had trouble, as I understand it, not so much in the rumbling and upheaval as in the character of the base and filling for the pavements. I do not see how it is possible to use a broken stone base with a sand cushion without losing all of the sand between the broken stone; the sand will be washed into the spaces between the broken stone used in the foundation, leaving the surface in very bad shape. It is necessary, however, to level up the foundation to get a uniform base upon which to lay the brick. From my own experience I do not think it possible to roll unequal brick to a true surface on either a 1 or 2-inch cushion. They must be sorted or sized in laying. On a street on which we were using a 1-inch cushion of sand this season there came on a heavy rain, and the water ran down from the center to the gutters and washed the sand away, and the brick had to be relaid.

Mr. Mann.—Because of the broken stone base?

Mr. Norton.—No. It was on a concrete base.

Mr. Ricker.—The sand was washed crosswise into the gutters?

Mr. Norton.—It was washed from the center to the side, through the joints, which necessitated taking up the pavement. Small depressions showed along the center of the street after it was cemented; when taken out the sand was found to have been washed out by the rain. It does not seem possible to use sand with broken stone without losing all of the sand filling. In the matter of the

rumbling noise, it has been general in the West. There are cases where the pavement, laid in cold weather and afterward cemented at a low temperature, has expanded a certain amount, probably due to the expansion of the brick and cement. If the brick were laid in very warm weather and thoroughly wet in cementing, they would be cooled down to the temperature of the water with which they were flushed, and the brick and cement would afterward expand from the temperature of the water to that of the air. Pavements may be laid in a temperature of 80 or 90 degrees, but the brick would be at a temperature considerably below 50. Raising the temperature above 100 would be sufficient to account for considerable expansion.

Mr. March.—If a broken stone base is used I think it is important that some filling other than cement should be used. In reference to the 2-inch sand cushion, in Buffalo, where it is customary to lay concrete for asphalt topping, the top has been left rough in order to get a better bond for the topping, and this has expanded so much it is necessary to leave a joint in the concrete when laying the pavement, and in that case, where the top of the concrete is rough, the cushion could be increased; that is, a thicker cushion would be advisable in order to compensate for the inequalities of the concrete and brick. If the sand is pushed aside the brick would rest on the stone, so, in case of a rough top, it strikes me a 2-inch cushion would be advisable; if the surface is smooth it is not so necessary, and possibly a 1-inch cushion would do.

Mr. Ricker.—There is a special claim made for brick made of certain chemicals. Do you know anything about this?

Mr. March.—I saw reference made to them in some magazine within the last week. They are composed of coal ashes and chemicals, and require no burning. They are ready for use in five hours after being made.

Mr. Mann.—Put in the presses and molded?

Mr. March.—I suppose so.

Mr. Green.—Slag brick are used in Toronto. Simply for a toothing along car tracks, laid in 2-inch sections.

Mr. Norton.—Another point to be considered is in the laying of the brick across the street and making the joints tight. If too tight, in rolling it will make an arch across the street, and no kind of filling will prevent that trouble.

Mr. Mann.—If brick and stone of the same size are laid on the same bed, the brick will produce more noise than the stone because of its metallic ring. Is this not so?

Mr. March.—Yes. Every pavement has its defects just as

anything else. The question is, which has the least at the least expense?

MR. RICKER.—In case of brick between the rails of car tracks, do you know whether the expansion is sufficiently distributed to the gauge?

MR. MARCH.—I do not know.

MR. RICKER.—What I had in mind is, it is sometimes necessary to pave between the tracks and outside of the rails, leaving parts of the street unpaved. What would be the effect?

MR. MARCH.—The effect of expansion. Expansion makes the brick rise.

MR. RICKER.—Another trouble would be, a roll forms on both sides where there are hollow spaces under the girder rails.

MR. MANN.—There is only a little space where the rails are bolted together.

MR. RICKER.—Of course they have to have room for the joints.

MR. MARCH.—I do not think it would be a serious defect.

MR. NORTON.—The trouble has been that the pavement expanded over long blocks of the pavement rather than in the narrow gutter.

MR. MARCH.—It seems, however, to occur only in a very small area, about three feet square, as on Oakdale place. Most of the trouble of any amount is in a small area.

MR. RICKER.—Are the brick laid closer at the ends than at the sides?

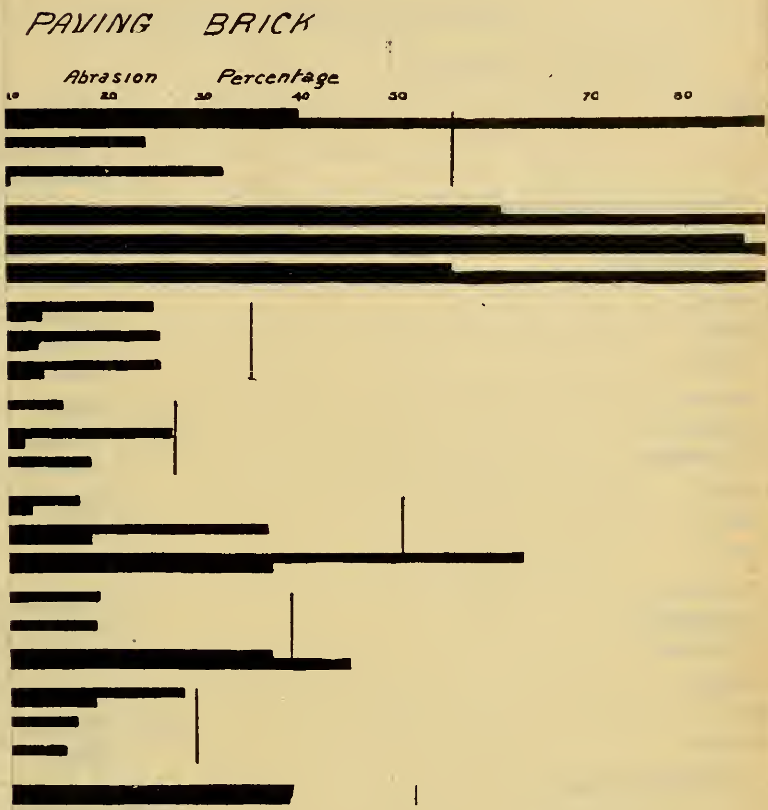
MR. MARCH.—The sides are not supposed to lay as closely as on the ends. If any filling is placed between them it is liable to cause transverse cracking across the street; any expansion, of course, would be noticeable there. On McDonough street, Brooklyn, the brick arched up that way, I believe, and though an attempt was made to roll it down with a 15-ton roller it was without effect. They took out a line of brick along the curb, but it had no effect. It was a regular brick arch.

MR. MANN.—If the cracks are shown transversely across the street, then the expansion is transverse.

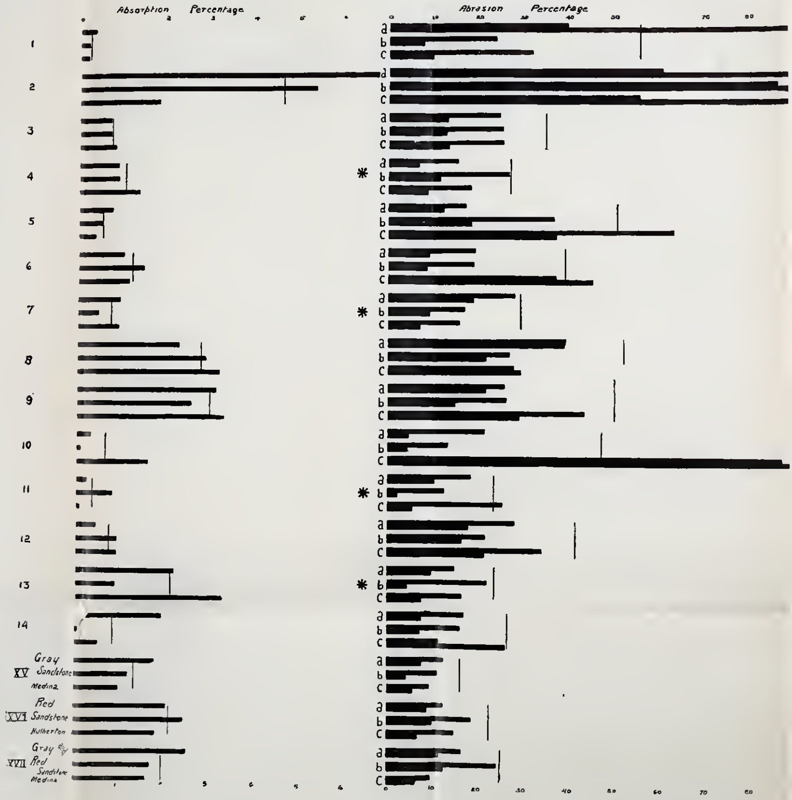
MR. MARCH.—That is probably true. It probably has no defects at all on its surface, caused by the ends of the brick being laid closer than the sides.

MR. NORTON.—It is the tendency of the men laying the brick to lay them in this manner. Probably the filling between the brick has driven them up. Closing the joints at the ends with broken brick makes the joint across the street very much closer.

MR. MARCH.—Care ought to be exercised in the selection of the


PAVING BRICK
Abrasion Percentage
10
20
30
40
50
70
80

COMPARATIVE TESTS OF PAVING BRICK



Bricks previously dried on furnace 94 hours, then immersed 48 hours.
The vertical black line shows the average absorption.
Three bricks, a, b, c, of each kind were tested.
Numbers 1 to 14, inclusive, were bricks.
Numbers XV, XVI, XVII cut to brick size—Medina sandstone.

The bricks were first tumbled for 1 hour, the loss in which is shown by the upper line.
The bricks were then tumbled again for 2 hours, the loss in which is shown by the lower line.
The average total loss is shown by the vertical black line.
In the first tumbling 112 pounds scrap iron and 120 pounds pig iron were used.
In the second tumbling 112 pounds scrap iron only were used.
Rattler 3 feet long by 2 feet diameter, 30 to 35 revolutions per minute.

* These brick selected as acceptable.

BRICK TESTS

RESULTS
f
...lt or spall ...ack ...ack
...bout from 2² to 2.⁴ ...l
advantage to deeper brick ...is so in actual practice ...h ...re
...0 lbs or more per sq in when tested flat ... .. according to his sample No. 6 truly first class Test equal in value to Absorption & Abrasion Tests
...sc ...c
...ss than ...r sq. in ... from ...rick
of much value since in actual practice the pressure with only about 1000 lbs per sq in loaded with ½ ton is abt ½ to ⅔ strength flatwise ... 3/4 "
..., truly first class product – 1.5 %
...on must not exceed 3 %
...ion must not exceed 2 %
...orption Limit 2% for assurance of brick being sufficiently compact
... of Brick divided by

STREETS PAVED WITH BRICK IN BUFFALO N.Y.

When Laid: Year	When Laid: Month	Street	From	To	Contr	Filling of Joints	Length	Width	Square Yards	Total Cost	Cost per Sq Yd	Kinds of Brick	Traffic	Condition Nov 1 - 1896
1889		Coe Pl	Main	Ellicott	Private Party		576	15	974			Common	Light	Poor Edges Chipped
1891	Oct	Purdy	St R R Co	Puffer	Buffalo Pav'g Co	Drain Tile [illegible]	775	24	2061	5154	2.49	Syracuse	Medium	Edges Chipped
1892	Oct	Clay	Austin	Mily Rd	"	"	1110	28	3466	9880	2.85	"	Medium	Edges Chipped Gen'l Depression from Main Sewer
	Oct.	Danforth	Forest	Bradley	"	"	799	28	2487	7099	2.85	"	Medium	Edges Chipped
	Oct	Dart	Forest	Bradley	"	"	796	30	2654	7754	2.92	"	Medium	Edges Chipped At about 100 ft from Bradley there is a rise of 4" at 3/4 of the width
	Oct	Tryon Pl	Auburn	Forest	"	"	3220	26	10723	31357	2.92	"	Medium to Heavy	Edges Chipped
	Oct	Oakdale	Seneca	South End	Private L. K. Suor	Cement Jts	428		1238			[illegible] Porter	Light	Generally Fair 3 or 4 Bulges where pavement has raised
1893	Sept	Barry Pl	Bird	Forest	P B McNaughton	Drain Tile Cement Jts	642	30	2140	6257	2.92	Syracuse	Medium	Good
	July	Eastwood	Main	Humboldt	Buf Pav Co	Cement Jts	1136	24	3083	9542	3.09	"	Light	Brick uneven top surface Edges Chipped
	Sept	Franklin	Church	Niagara	Queen City Paving Co	[illegible] Cement Jts	539	34-37	2796	6400	2.29	Franklin	Heavy	Generally Fair Some soft brick
	July	Gatchell	Broadway	W.S.R.R	P B McNaughton	Drain Tile Cement Jts	1446	24	3858	11219	2.90	Syracuse	Light	Good Many Joints open 1/4 inch along center
	May	Hanley	Forest	Letchworth	Buf. Pav. Co	"	1622	30	5407	15689	2.90	"	Medium	Fair Edges Chipped
	June	Milburn	Broadway	N Y C R R	"	"	1686	28	5245	14525	2.76	"	Light	Good
	May	Penfield	Niagara	West Ave	"	"	487	26	1409	4286	3.04	Franklin	Light	Generally Fair A few longitudinal cracks
	Sept	Peterson	Fillmore	Mills	"	"	775	26	2239	6862	3.03	Syracuse	Light	Good
	July	Shepard	Broadway	W S R R	P B McNaughton		1444	24	3850	11185	2.90		Medium	Good Joints open along center
1894	Oct	Roos Al.	Broadway	William	O T Dutro		1310	19 1/2	2838	7935	2.79	Mack Blk	Medium	Fair Some soft brick A few longitudinal cracks Some depressions
1895	Sept.	Bank Al.	Court	South End	Buf Pav Co	Cement Jts	323	10 / 11	382	1072	2.80	Franklin	Light	Good
	May	Central	William	Lovejoy	D J Nugent	Drain Tile Cement Jts	1764	28	5488	14763	2.69	Mack Blk	Light	Good
	July	Douglass	Ellicott	Center	O T Dutro		462	32	1477	3379	2.28	Mack	Medium	Good
95-96		Laurel	Main	Michigan	Private L Gipp	[illegible] Cement Jts						Johnsonburg	No traffic	Good Not open to traffic A few longitudinal cracks
1896	June	Alabama	Elk	Sandusky	W H Kinch	Drain Tile Cement Jts	1127	30	8767	8939	2.37	Mack	Medium	Good
	July	Schiller	Queen	Vanderbilt	G W Binder	Cement Jts	2676	30	8920	20990	2.35	Mack	Medium	Good
1897	Aug	Preston	Ferry	Auburn	P B McNaughton	Drain Tile Cement Jts	1073	30	3577	5998	1.67	[illegible] Porter	Medium	
	Aug	Pooley Pl	Grant	Dewitt	L H Gipp	Drain Tile Cement Jts	1286	26	3715	8700	2.34	Franklin	Medium	
	Sept	Miller	Broadway	Walden	P B McNaughton	Drain Tile Cement Jts	2739	28	8528	19031	2.23	Mack	Medium	
	Oct	Pine	Broadway	Cypress	L H Gibb	Cement Jts	300	32	1068	2100	1.97	Porter Blk	Medium	

VARIOUS METHODS OF PAVING BRICK TESTS

	Authority		Results
Lime Test	Mirnoeser; Chase; Baker	Immersed in Water: 3 days; 10 days; 5 to 10 days — Then Examined — Dried in Air 3 days	Should not split or spall; Should not crack; Should not crack
Specific Gravity		Formula $\frac{A}{I-W}$ Where A = wgt in air, I = wgt after absorption, W = wgt in water	Should range about from 2^{a} to 2^{a}
Cross Breaking Test	Johnson	Brick laid edgewise on two supports — Distance between supports 7 inches — Loaded until breakage — Breaking Load ÷ by width of brick — Gives Breaking Load per inch in width of surface as the brick stands when laid	Gives advantage to deeper brick which is so in actual practice
Transverse Test	Chase; Baker	Formula $R = \frac{3wl}{2bd^2}$ or $W = \frac{2bd^2}{3l}$ Where R = modulus of Rupture, w = total wgt to break brick, l = length in inches, b = breadth, d = depth — Brick laid on knife edges 6 inches apart — More uniform results from testing Brick flat	Should be 1600 lbs or more per sq in when tested flat; " " according to his sample No 6 truly first class; Considers this Test equal in value to Absorption & Abrasion Tests
Crushing Test	Johnson	Applied on pieces 2 x 3 x 4 deep — Load Sustained ÷ by area in square inches of loaded surface — Gives Strength of Specimen in pounds per square inch	
	Nicholson	Applied on 2 inch cubes — Surfaces ground down to parallel planes	Should not be less than 14000 lbs per sq. in on 2 inch cubes from any part of brick
	Baker	From Experiments on Soft Brick The strength of a 1/4 brick, 1/2, 3/4 and whole brick are to each other as 3, 4, 5, 6 respectively	Does not consider of much value since in actual practice the pressure with 1 1/2 inch tire is only about 1000 lbs per sq in loaded with 1/2 ton; Strength endwise is abt 1/2 to 2/3 strength flatwise; edgewise 3/4 "
Absorption	Baker	Specimens thoroughly dried out 6 weeks to 6 months — Weighed and Immersed in Water 24 hours — Dried and Weighed again	Sample No 6 truly first class product Absorption 1.5 %
	B P W Buffalo; Chase; Holman	Weighed and Immersed in Water 48 hours	Buffalo: Ave. Absorption must not exceed 3 %; Chase: Ave Absorption must not exceed 2 %; Holman: Desired Absorption Limit 2 % for assurance of brick being sufficiently compact
Abrasion	Johnson	Rattler steel lined 30" long 24" diam — Revolutions per min 40 — 5 whole bricks 5 similar granite 10 cast iron blocks 6 lbs ea — No Cushioning Material used	Average Loss of Brick divided by Average Loss of Granite Gives Comparative value
	Baker	Rattler Wooden Staves Iron Heads 3-9 1/2 x 25" diam — Revolution per min 24 — 546 pcs foundry shot or 1/2 lb total 83 1/2 — Time of Running 3 separate half hours	Sample No 6 truly first class; " " " as good in Abrasion as Quincy Granite
	B P W Buffalo N Y	Rattler Iron 3 long 2' diam — Revolutions per min 30 to 35 — 1st tumbling 100 pcs scrap iron and old brick [illegible] — With all 7 different brick — 2nd tumbling 100 pcs scrap iron with brick — Time of Running 1 hour each tumbling	Best Brick tested as well as ordinary Paving Sandstone; Maximum Abrasion Per Cent should not exceed 30 %
	Orton and Harrington	Rattler varying in size — 1st Max Loss obtained by filling bbl 15 % [illegible] — 2nd Per Cent Loss independent of Length of Barrel with [illegible] condition — 3rd Per Cent Loss increases more rapid rate than speed from 20 to 40 revolutions — 4th Per Cent Loss decreases with equal successive intervals of time up to 80 min tumbling	Recommended Speed 30 Revolutions per minute Duration 40 minutes; The Use of Cast Iron Block in Rattler deprecated because of great Variability & Severity of Results upon the Brick
	Wheeler	Formula for Rating of Average Paving Brick $V = 5(18 - R) + 2(7 - A) + \frac{T}{220} + \frac{C}{1000} + \frac{10}{3^{25} - D} + \frac{10}{7^{5} - H}$ — The Mean of a large number of tests gave R = 8.00 per cent, A = 2.00 per cent, T = 2200 pounds, C = 10000, D = 2.25, H = 6.5; Thus making V = 100 and Rattler test most important	V = an arbitrary comparative rating; R = rattler loss in per cent of wgt of brick; A = absorption " " of total wgt of brick; C = crushing strength per sq in; T = modulus of rupture " "; D = specific gravity; H = hardness by Mohs mineralogical scale. Very good brick should exceed this value

COMPARATIVE CONSTRUCTION AND COST OF BRICK PAVEMENTS, IN VARIOUS CITIES

	City	Miles Dec. 31, 1896: Asphalt	Stone	Brick	Brick Course: Filling of Joints	Top	Bottom	Cushion	Foundation Course	Is Drain Tile used back of Curb?	Kinds of Brick used	Cost: Brick per M. delivered	Curbing per lin. ft. in place	Per Sq. Yd. Complete, Including Excavation, Curb, etc.	Results	Curbing, Minimum Dimension: Thickness	Depth	Length
1	Akron, Ohio		3	7.3	Formerly Tar. Now Portland Cement and Tar			Sand 2"	Concrete. Furnace Slag at 18c per Sq. Yd.	No	Akron & Canton.			$1.40 not including Curb		6	18"	30 to 72"
2	Albany NY	163,921 Sq. Yd.	Granite Block 492,360 Sq. Yd.	77,121 Sq. Yd.	Portland Cement & fine sand grout 1 to 1	One Course on edge, as close as possible	None	Screened Course sand 1½" when bricks are rolled	1:2:4 Concrete 6" thick. Broken Stone 2" or less in size	"	Canton Shale. Catskill	$15 to $16.50	45c to 75c Granite	$1.85 to $2.06 Not inc. curb. Av. price abt $1.83	Quite satisfactory so far.	5" 6"	15 12"	42" Bluestone & Granite
3	Binghamton NY	3.83		0.7	Sand.	One Course on edge, laid close.	"	Sand 1"	6"	"	Corning	$14	60c Bluestone.	$2.40	Unsatisfactory	4"	30"	24 to 48" Various
4	Bloomington, Ill			20	"	"	One course flat. Part with St. line.	"	4" well rolled cinders and sand.	"	Bloomington & Springfield Ill.	ab $8 or $9	ab 40c Sandstone	$1.40 to $1.60	Very satisfactory	60	24"	Not less than 36"
5	Boston Mass	8.91	82.24	0.48		Have laid no Brick Paving in five years, except one small experimental piece in 1894							$1.00 Granite			7"	22 Granite.	72"
6	Brooklyn NY	36.6	133 Cobble 260	0.32	Portland Cement 1:1	One Course [illegible] laid close	None	Sand 1½"	1:2:4 Am. Cement Concrete 5" & 6" thick	"	Mack, Canton, block 3"×4"×9"	$20 to $22	65c to 75c	$2.55	Fair	5"	19"	42 to 90
7	Buffalo NY	197.6	116.5	4.26	Formerly pitch. Now Cement [illegible]	"	"	Sand 1"	1:2:5 Concrete 6" thick	Yes 30" below top of curb.	Syracuse, Franklin, Porter, Mack	abt $14 to $16	abt 45c Medina Sandstone	Formerly $2.75 Now $2.35	Fair to Satisfactory	4"	18"	30 to 36"
8	Burlington, Iowa							3"			Vitrified	$10	40c	$1.30 besides curb.	Fair	36	30"	
9	Canton, Ohio		1.?	13	Formerly pitch. Now Cement	"		Sand 2"	Crushed Limestone 8"	No	Canton 3½×4×8"	abt $8.00	35c Ohio Sandstone	Formerly $1.85 Now abt $1.00	Quite good	6	20 to 24	36 to 96
10	Cedar Rapids, Iowa			10.00	Sand	"	abt 25 m. of double course. Bal. single on 6" Macadam	Sand 2"	Macadam 6"		Galesburg & Des Moines.	$9.50 to $11.00	Limestone 50c Berea 55c Cement 36c	Formerly $1.79 Now $1.16 Not inc. Curb	Not Satisfactory. [illegible]	5"	22"	48"
11	Charleston W. Va.			8.5	"	"	None	Sand 2½"	Sand 3" Tarred Boards 1"	"	Porter, Kanawha Pavers and others	$13.00	55½ Sandstone	$1.35 Curb not included	Satisfactory	6	24"	36"
12	Cincinnati Ohio	20	Granite 45	35	Coal Tar pitch	"		Sand 2"	1:2:5 Concrete 6" thick	Yes. 30" below top of curb.	Harris, Porter, Columbus, Hallwood, Buckeye, Athens, Metropolitan, [illegible]	$15.00 to $20.00	$1.15 Granite	$2.00 Without curb.	Fair to Satisfactory	5"	21"	60" Av. 84"
13	Cleveland Ohio	5.03	37.4	51.81	Asphaltic & Cement.	Lug Brick		None	Sand	Yes	Massillon, Canton, McAvoy, Porter, Clev. V.F. [illegible]	a $13	Medina 28c Berea or Amherst 28c	Formerly $1.25 Now $1.40	Generally fair	5	20"	42 to 48
14	Clinton Iowa			2.14	Sand	One Course on edge, laid close	"	Sand 2"	Rubble mixed with sand 6"	No	Galesburg, Linden Mills, Rock Island, Le Claire	About $11.00 to $13.00	50c to 67c Clev. Sandstone	$1.60 to $1.70	Satisfactory.	60	18"	4'
15	Columbus Ohio				Pitch	"	"		Broken Stone 8"	"	All kinds Mfd in Ohio.	$10.00 to $15.00	Berea 35	Formly $1.75 to $2.25 Now $1.00 to $1.50 Exclg. Curb	Bad to Satisfactory.	5	36"	Not less than 36"
16	Davenport Iowa			14.3	Sand	"	"	"	1:2:3 Concrete 5"	30" below top of curb	Galesburg Buffalo Iowa	$11.00 to $13.00	38c to 43c Ohio Sandstone	$1.24 Not inc. Curb or Exc	Fair to satisfactory	5	18 20	36"
17	Dayton Ohio	16.47	158	9.69	Formerly Pitch. Now Cement	"	"	"	1:2:6 Concrete 6"	No	Hallwood, Hayden Blk, Hocking, Porter, Canton Repress. East Clayton.	abt $14.00	50c to 56c Limestone	Formerly $2.40 Now $1.87	Good	5"	18	42
18	Detroit Mich	135.7	10.00	16.61	Pitch	"	"	½"	1:2:5 Concrete 6	Yes 24 below top of curb.	Nelsonville, Athens, Canton, Mack, Hallwood, Hayden	abt $14.00 to $18.00	Medina 70c Berea 45c	Formerly $2.20 Now $2.08	Fair to Satisfactory	4	16	48
19	Dubuque, Iowa	[illegible]	70	3.15	Sand	One Course	None	Sand 1½	6 Concrete 6" Macadam Gravel	No	Galesburg, Des Moines, Lehigh	$10.00 to $12.00	28c to 33c Limestone	Formerly $1.?? Now $1.?? Not including Curb	Fair to satisfactory	6"	24	36
20	Dunkirk NY		7.5	3.?	Portland Cement grout	One Course set on edge laid close.	"	1"	Brick gravel 5" or 1:2:3½ Concrete 6"	No. 18" below sub grade 18" inside curb	Brady Run, Park.		30c to 35c Clev. Sandstone	$3.55 $1.78	Excellent	5"	18	36"
21	Easton Pa			1.40	Pitch and Sand	"	"	2"	1:2:4 Concrete 6"	No.	[illegible]	[illegible]	Limestone 55c [illegible] Bluestone 55c	Formerly $3.05 Now $2.?? Exc. of curb	Satisfactory	4	20	
22	Evansville Ind			20	Sand				Concrete 6"		Evansville, Porter, Hallwood, Stanton, Scioto	Evansville $11. Porter etc. $14.	47c	$2.??	Fair	5"	22	48
23	Galesburg, Ill			15	"		One course [illegible]	1½		No	Galesburg	Formerly $10.?? Now $9.??	45c Berea sandstone	Formerly $1.?? Now $1.50	Satisfactory	5	20	30 to 60"
24	Hartford Conn.			0.11	Pitch		None	1"	Macadam rolled hard		Hallwood	$34.35	65c Granite		Fair to Satisfactory	5	24"	48 to 54
25	Indianapolis Ind	33		[illegible]	Cement 1:1 also Asphaltic Cement			2"	1:2:4 Concrete 6" thick		[illegible]	abt $15.00 f.o.b. [illegible]	60c [illegible] curb & gutter	$2.00		5	24	60
26	Kansas City Mo.	Oct 1 [illegible]	[illegible]	1896 [illegible]	Sand Cement grout or Murphy				4" & 6" Macadam 6"		Pittsburg, Kas. Diamond, Kansas City Vitrified	$11.00 to $12.00	45 Limestone	[illegible] Hallwood Curb	[illegible]	5	24	48"
27	Kenosha Wis.			1.5	Sand			1½	Macadam 6" thick.		Galesburg Standard Repressed	$14.00 f.o.b. Kenosha	Berea 42c	$1.?? Exc. of curb.	Satisfactory	60	20	48
28	Lafayette Ind.			1.9			One course common flat		6" Pit Gravel		Decatur, Bloomington, Veedersburg, Clinton, Canton	$13.00 to $16.00	all sorts	$1.?? Exc. of Curb	[illegible]	4" 5" 6"	20" 22" 24"	48" 120"
29	Lincoln Neb			13	"		One course laid flat.	1"	Sand 6"		Lincoln.	abt $12.00	Colorado Sandstone abt 75c	$1.25	Fair to Satisfactory	4"	20"	36"
30	Lockport NY	1		2.4	Portland Sand & Murphy Grout Filler.		None.	2"	1:2:5 Concrete 6" thick		Porter, Mack, U.S., Canton, Penn.		abt. 40c	In 1893 $2.?? to $1.?? in 1896		4"	15"	30
31	Louisville, Ky	6.68	23.40	7.20	Pitch				1:2:5½ Concrete 6"		[illegible]		Limestone 65c	[illegible]	[illegible]	6"	22"	60"
32	Memphis Tenn	[illegible]	10	5	5 Coal tar pitch with 10% Trinidad Asphalt			1½	1:2:3 Concrete 7" thick		Tennessee [illegible]	abt $15.50 [illegible]	Georgia Granite 42½c	Formerly $3.?? Now $2.??		6"	20"	36"
33	Minneapolis Minn	10	10	1	Asp. Cement Murphy Grout				1:2:5 Concrete 6" thick		Des Moines, Galesburg, Purington, Streator	$14.00 to $15.00	Granite 73c	$1.?? Exc. of Curb.	Not in use long enough	6"	20"	48 to [illegible]
34	Newark NJ	18.0	69.14	8.63	Gem Grout Sand Pitch			1½ 2"			[illegible]		Bluestone 60c set in Concrete	$2.?? [illegible]	Satisfactory	4	20	48"
35	Niagara Falls NY	16		2.?	Formerly Port Cement [illegible] Now [illegible] Cement			Formerly Sand [illegible] Now [illegible]	1:3:10 Port Cement Concrete 6" thick	Yes. 28 below top of curb	Mack, Park, Canton [illegible]	abt 14 to 16	Medina abt 60c	Formerly $2.?? and $2.?? Now $2.??	Good [illegible]	Formerly 6" Now 4"	Formerly 22 Now 20	36
36	Omaha Neb	23.40	24.5	10.7	Sand	One Course only set on edge			1:2:5 Concrete 6		Galesburg, Des Moines, Kansas City, Repressed	$14.00	abt 59c	$1.?? Without Curb	Poor to Fair	5"	20"	36"
37	Peoria Ill	6.??	13.??	12.??	Sand and [illegible] Port Cem grout [illegible]			Sand 1 to 2"	1:1½:4 Port Cement Concrete 6"		[illegible]	$11.00 to $12.00	[illegible]	$1.?? to $1.??	Satisfactory	5" Max 6"	20 36"	48" 48"
38	Providence R.I.	3.39	28.88	0.48	Port. Cement	One Course set on edge laid close	None	Sand 1"	1:2:4 Concrete 6" thick.	No		$11.00 to $12.00	Granite 75c	Last Contract $2.49	Good for light travel, but not for heavy.	7"	18"	60"
39	Rochester N.Y.	25.33	29.58	4.13	Pitch.	"	"	"	"	Yes	Canton, Syracuse, Porto Block, Johnstown, Hallwood Block	"	.80c	Without Curb Formly $2.25 Now $1.84	Good	6	18"	36"
40	Rockford, Ill			1.82	Sand		One Course laid flat. Part with St.	Single Course Sand 2". Double Course 2" for bottom 1" second	Rubble and Sand. Rubble diam 3½ to 1"	No	Galesburg	abt $11.00	Sandstone 65c	Single Course $1.57 Double $1.75	Satisfactory	4"	24"	48"
41	Rock Island, Ill			5 / 4			Flat	Sand 2" / 5"	Broken Macadam 6" / 6" Mac. Rolled with 10 Ton Roller	No. But in some cases in C. of St. 36 below grade	Bardolph, Rock Island, 3 or 4 makes of Galesburg.	$10.00 to $12.00	Cleveland has been 60c Now abt 45c	Formly $1.60 to $1.?? Formly $1.30 Now $1.20	Satisfactory where quality of Brick is 1st class	4"	20 to 25"	36
42	St. Joseph Mo.	5.83	0.10 Mac. 29	4.62	Sand	"	One Course laid flat on 4" Sand.	1"	6" of Broken Stone & Sand often used in which case the bottom course of brick is omitted.	No	St. Joseph	$10.00	Port. Cement 60c Limestone 65c	$2.00	Not Satisfactory except on Residence Sts.	5"	24"	30 Av. 48"
43	St. Louis Mo	903 Asphalt 26.46 Macadam	4.58 Granite 0.80 Limestone 0.35 Wood	43 3/5 Telford 6.82 Brick	Formly Sand Now Portland Cement Grout.	One Course set on edge.	None	1"	Concrete 6" thick		St. Louis Pressed Brick Co's	a $13.00	Granite on Concrete 6" deep, 12" wide & backed with Conc. 6" Brick 16 deep 80c to $1.00	$2.50 to $2.00	Satisfactory.	5"	16	54"
44	Scranton Pa	10.46	1.67 Cobble 2.16	0.11	Cement and Pitch	One Course set on edge, laid close.	"	2"	1:2:7 Concrete 5" thick	"	Scranton, Mack.	abt $13.00 to $16.00	Bluestone. 5×24 45c 6×30 56c	abt $1.65 Curb extra.	Satisfactory	4"	24"	36" Av. 60"
45	Springfield Ill.				Sand.	One Course on edge	"	1½"	1:1½:4 Concrete Stone also 1:5 gravel 6" thick.		Springfield.	$8.00 to $10.00	Berea 45 "	$1.05 97c	Very "	4"	36"	36"
46	Syracuse, N.Y.	11	5	8.1	Port. Cement 1:1 Some Asp. Cement.	"	"	½"	1:2:5 Rosendale Cem't Concrete 6"	Yes 36" below top of curb	Syracuse, Corning, Canton & Malvern, Hallwood Blk	$11.00	65c to 80c Inc. Concrete and Cobble Drain.	Av. $3.00	Fair	5"	16"	48"
47	Terre Haute Ind	2¼	00	3⅓	1:1 Cement	One Course set on edge laid close.	"	1"	2:3:6 Concrete 5" thick	No. 6" gravel under Curb	Canton, Veedersburg, Clinton, and latest Terre Haute [illegible]	abt $12.00 to $14.00	Hard Limestone 50c	Formly $2.60 Now $1.70	Unfavorable. Dubious to Good.	4"	18"	36 Av. 54
48	N. Tonawanda and Tonawanda N.Y.			32 / 4.25	1:1 Cem. grout. Formerly sand.	"	"	1¼ to 1½"	Formerly 8" Broken Stone. Recent 6" Concrete	No. Will be in future	Mack, Canton, Porter, Jamestown, Freeman, Franklin.	$11.50 to $17.15 / $12 to $14	Medina sandstone ab 35c	Formly $2.56 Last $1.96 Formly $2.28 Last $2.34	Satisfactory to very Satisfactory	4"	18"	36"
49	Toronto, Ont.	16	07.5	4.5 to 5	1:1 Grout and Pitch	"	"	1 to 1½	1:3:6 Port. Concrete 4" to 6"	Sometimes Back Front Center.	Canton Shale, Local Repressed	$12.00 $14.00	65c Credit Valley Sandstone.	$1.65 without Curb. $1.25 on Sand	Fair to Satisfactory	4	20"	48"
50	Trenton N.J.	Asp't Block 18	101,080 Sq. Yds.	124,828 Sq. Yds.	Port. Cement Grout until ½ full then 1:1 fill full.	"		1"	1:2:5 1:2:6 1:2:7 acc'g to size of stone. Port'd Cement only used. 6" thick	Do.	Trenton, State Line, Canton Shale, Monaco, Porter, Mack	$15.00 to $20.00	30c to 35c	$1.63 to $2.25 Not inc. Curb.	Very Good.	4"	16"	36"
51	Troy N.Y.	4.2 Including 2 Blks Asp. Block	17.3	3.6	Formly Pitch Now 1:1 Port. Cement	"	"	1½	1:2:5 Concrete 6" thick	On Side Hill Sts only.	Porter, Canton & Mack, both Shale and Fire clay.	abt $24.00 Nearly 60% for freight & cartage	Hudson River Bluestone abt. 80c	$2.50 to $2.06 Exc. of Curb	Fair to Satisfactory	5"	20"	48"
52	Washington D.C.	117.9 Asphalt 14.04 Asp. Blk	43.2 Cobble and Granite	0.2	Only above amount on Streets, Brick Block used in Alleys			1	1:2:6 Concrete 4 thick	No.	Porter, Mack.	$20.00 to $22.50	87c to $1.00 8×8 on hyp. [illegible] 6×20 " [illegible]	$2.00 Excl. Exc. and Curb	"	8" 6"	8" 20	72 to 120
53	Youngstown Ohio	4	1	3	1:1 Cement	One Course on edge laid close	"	1"	1:3:6 Port. Cement Concrete 4" to 6 thick.	Only in special cases	Brady Run, Canton	$10.00 to $12.00	Sandstone 30c to 35c Cement with gutter 18 wide abt 70c	abt $1.75	Fair to Satisfactory	5	18"	5'
54	Wilmington Del.	Dec. 31, 1896: 0.48	36.40	5.26	Sand. Some Pitch. Cement on abt 2 miles		"	1" to 2"	2 Blocks laid as sample. 1:2:5	No.	Porter, Canton, Mack, Zanesville, John Porter Co.	$20.00 to $23.00	Brandywine Granite, 59c	$1.29 to $1.51 Without Curb	Fair	5"	18"	60 to 120
55	Philadelphia Pa	1896: 153	331	76	Cement			1"	Concrete 4 thick	"	No Special Brands. Brick must be 1st quality.	City does not buy paving material.	Granite 6" 81c 8 94c	Without Curb. Av. $1.70 per Sq. Yd.	Satisfactory	6"	22"	72"

cement for joint filling and foundation. In the Franklin street pavement we used Royal Crown Belgium Cement in front of the City Hall. The brick of the Franklin street pavement has been generally good. There are one or two places that are bad.

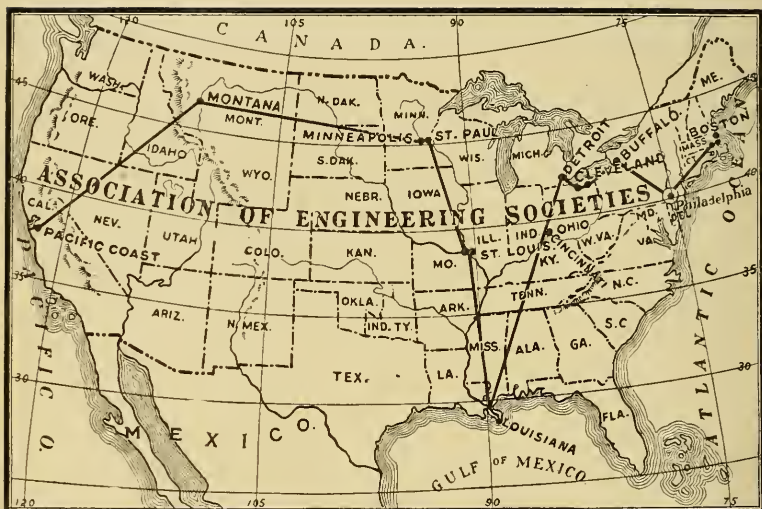
MR. NORTON.—It shows a rumbling in one or two places.

MR. MANN.—Maybe Mr. Vander Hoeck can tell us something about the pavements in Holland?

MR. VANDER HOECK.—There are several miles of highways paved with brick in Holland. I am sorry to say they are in very bad condition. They were laid years and years ago. There was no attempt made to get a good foundation, and the bricks were simply laid in sand; consequently the pavement is full of holes, and very expensive to keep up.

MR. VANDER HOECK.—I do not know exactly where the trouble is, but I thinks it is in the foundation; and in some places the mud will come out between the brick. As far as the brick is concerned, I do not think it will be very easy for the makers to make brick conforming to a certain standard to last 200 or 300 years.

MR. MANN.—I went into an old mission in Ahualulco, Mexico. In front of the altar were the distinct marks of the knees and toes of the worshipers worn out in the brick. In the doorway it was worn down to not more than one inch in depth. The brick were set on edge. They were regular sun-dried brick.


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
PACIFIC COAST
LOUISIANA
GULF OF MEXICO
MEXICO.
PACIFIC O.
ATLANTIC O.
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
KY.
W.VA.
VA.
MD.
ME.
MASS.
TENN.
N.C.
S.C
GA.
ALA.
MISS.
ARK.
OKLA.
IND. TY.
ARIZ.
N. MEX.
TEX.
LA.
FLA.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. SEPTEMBER, 1899. NO. 3.

COVERED RESERVOIRS.

BY FRANK L. FULLER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, May 17, 1899.*]

FRANKLIN, N. H., RESERVOIR.

IN 1889 the writer designed a covered masonry reservoir in connection with a system of water supply for the town of Winchendon, Mass. The system was not built at that time, but the same reservoir design was used in 1891 in connection with a water works system for the town of Franklin, N. H.

A section of that reservoir and also a cut from a photograph are given. The brick piers supporting the roof are 12 x 12 inches, laid in Portland cement. The roof is of hard bricks laid in Rosendale cement and 8 inches in thickness.

The average load at the base of each pier is a little less than 23 tons per square foot.

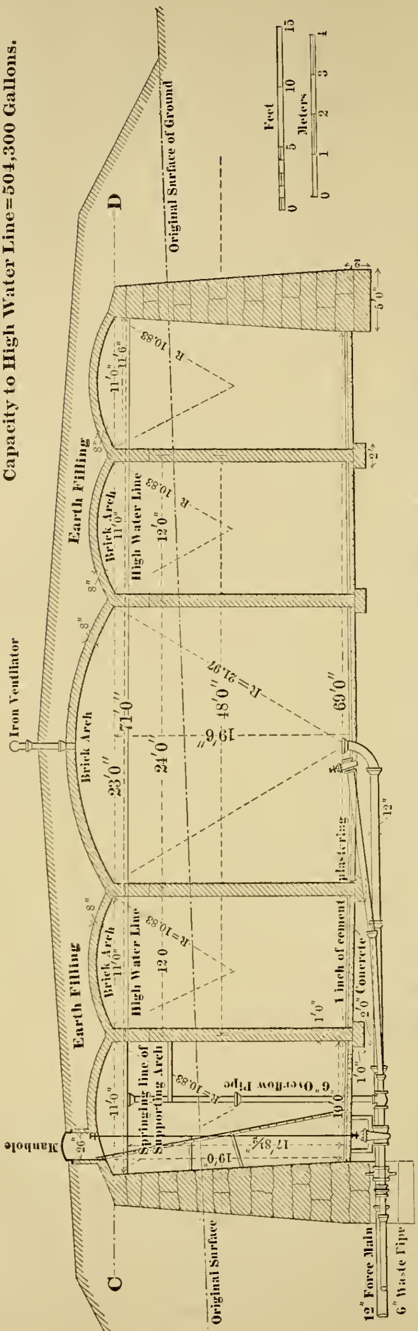
As the Winchendon reservoir is similar in construction, the detailed description of that reservoir given further on, will answer for this, and also largely for the Methuen reservoir.

The Franklin reservoir was the second covered reservoir built in New England, and the first circular one.

A copy of the final estimate for its construction, which was by contract, will give its cost in detail:

* Manuscript received August 30, 1899.—Secretary, Ass'n of Eng. Socs.

Capacity to High Water Line=504,300 Gallons.

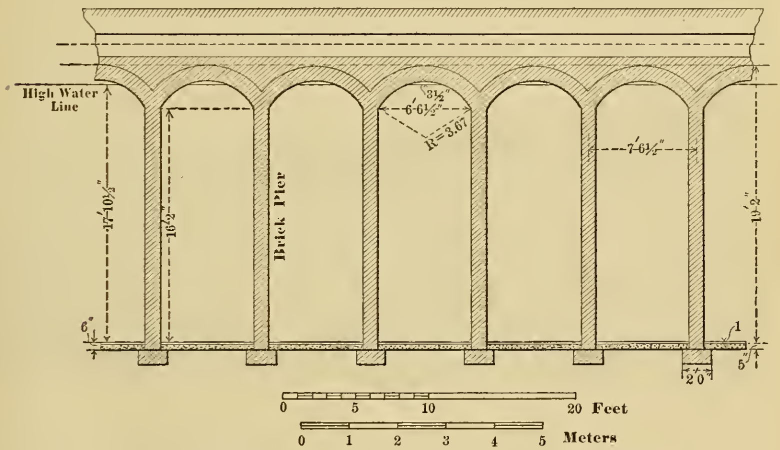


Circular Covered Masonry Reservoir at Franklin, N. H., Water Works.

2882.4 cubic yards earth excavation	@	$0.40	$1,152.96
714.8 " " local rubble masonry in Am. cement	@	6.80	4,860.64
18.6 " " Portland cement brickwork	@	16.96	315.46
120.8 " " American " "	@	13.96	1,686.37
57.5 " " " " concrete	@	6.75	388.12
410.8 square " 1-inch Portland finishing coat on bottom	@	45	184.68
464.4 " " ½-in. Portland plaster coat on sides	@	.40	185.76
52.5 lineal feet 12-inch cast iron pipe laying	@	.50	26.25
73.9 " " 6 " " " " "	@	.35	25.87
Extra for 40 barrels Portland cement on bottom	@	1.80	72.00
" " 2 " " " used around pipes and gates	@	3.48	6.80
" not included above			127.45
			$9,032.36

METHUEN RESERVOIR.

In 1893 a covered masonry reservoir of a capacity of 1,013,000 gallons was built by the town of Methuen from plans by the writer. It is similar in design to the Franklin reservoir, but has an inside diameter of 95 feet at the top and 93 at the bottom. The piers are



SECTION OF OUTER RING OF PIERS AND SUPPORTING ARCHES F.—F.
The Inner Ring of Piers is the same except that the piers are 2 inches longer.

also larger and the reservoir deeper. It is practically an enlargement of the Franklin reservoir by the addition of another circular covering arch of the same span and rise.

The roof is supported by 60 brick piers 16 inches square, laid in Portland cement.

The dome and covering arches are of brick, 8 inches in thickness, laid in Rosendale cement. The average load per square foot at the base of each pier is about 14.1 tons. This includes a possible load of 50 pounds per square foot for snow and ice in the winter.

The earth covering over the roof has a slope of about 1 in 38. The embankment about the masonry wall where it is above the original surface of the ground has a slope of 1 in 2.

The height of the middle row of piers from the bottom of the reservoir to the springing line of the lintel arches is 18.25 feet. The piers are 7.54 feet apart on centers, measured along the circumferences of their respective circles.

When full, there is a depth of 19.7 feet of water in the reservoir.

All materials were furnished by the town of Methuen, and delivered at the reservoir site. All work was done by day labor, except in laying the rubble masonry wall. This was furnished by Mr. Wm. S. Marsh, of Lawrence, at $1.64 per cubic yard. The wall contained 1084 cubic yards. Mr. Marsh also put the plaster coat on

the inside of the masonry wall for the sum of 23 cents per square yard. This coat was composed of equal parts of Portland cement and sand.

The total cost of the reservoir, exclusive of land, was $16,-864.64.

HARVARD RESERVOIR.

In 1895 the writer made plans from which was built a small covered reservoir for use in connection with the water supply for the residence of Fiske Warren, Esq., at Harvard, Mass.

The reservoir is 22 feet in diameter at both top and bottom, and 13.5 deep. The walls are of local rubble stone, partly obtained at the reservoir site. The reservoir contains, when at high water level, 12 feet of water, or 34,100 gallons.

The roof is a circular dome 22 feet span and 3.5 feet rise. It is composed of brick laid in American cement, and is 8 inches in thickness.

The bottom consists of 6 inches of concrete.

The writer is unable to give the cost.

WINCHENDON RESERVOIR.

Bids for this reservoir were received November 25, 1895. It was built from plans made in 1889, and, as before explained, used in 1891 in building the Franklin reservoir. The only change made was to increase the size of the piers from 12 x 12 to 12 x 16 inches.

Like the others, the water to be stored in this reservoir was from an underground source. Hence it was decided to use a covered reservoir.

As built, the reservoir has an internal diameter of 69 feet at the bottom and 71 feet at the top. The depth of water is 17 feet 8 inches. The local rubble masonry wall is 5 feet thick at the bottom and 2½ feet at the top, and has a total height of 21 feet, 2 feet of this amount being below the bottom of the reservoir. The capacity to high water line, or the top of the overflow pipe, is about 504,000 gallons.

Two sets of brick piers, laid in Germania Portland cement mortar, 12 x 16 inches, connected by lintel arches, support two rings of brickwork, which in turn support the concrete dome at the center and two circular concrete covering arches. The brick rings are 12 inches, and the concrete roof is 8 inches in thickness. An embankment surrounds that part of the masonry wall which is above the original surface of the ground, and the filling is extended over the roof and properly graded and seeded to grass.

Test pits were sunk at the reservoir site in order to ascertain the location and depth of the ledge, which was known to exist. It was found impossible to entirely avoid the ledge, and considerable rock excavation was required at the bottom on the westerly side.

The rubble masonry wall was begun in April, 1896. The core was left until the wall had been built, when it was removed and placed in layers and wet and rammed about the back of the wall. The wall was built of local rubble stone, and considerable difficulty was experienced in obtaining it of suitable quality. The ledges in the vicinity were found to be unfit, and the wall is largely composed of split field boulders.

At the top of the wall a skewback was cut, from which to start the outer concrete covering arch. A derrick and hoisting engine were used in making the excavation and laying the wall.

The ledge was excavated to a sufficient depth to allow 6 inches of concrete being placed on the bottom. The ledge was more or less disintegrated, and but little of that removed was fit for use in the wall.

All piers rest on solid ledge, or on large granite blocks firmly bedded in the bottom.

The piers are laid in Germania Portland cement mortar, the lintel arches connecting them and the spandrel filling between them being of American cement brickwork 12 inches thick.

The covering arches and dome at the center are of Portland cement concrete 8 inches in thickness. The cement used was of the Germania brand, and the proportions were 1 of cement, 2 of sand and 5 of broken stone, not over 2 inches in its longest dimension. Centering for the entire roof was put in place before any concrete was used.

Before the covering arches or dome were started the embankment about the masonry wall was raised to the top of the wall and thoroughly rammed, thus assisting the wall to resist the thrust of the arches.

The concrete was put in place in sections bounded by radial lines. The positions of these sections of covering arches and dome were such that they were on radial lines extending entirely across the reservoir from circumference to circumference, thus tending to transmit any horizontal thrust to the rubble masonry wall.

The concrete was prepared by a gang of five or six men, who put it in place as soon as it was thoroughly mixed. The amount prepared at one time was one barrel of cement with the proper amount of sand and broken stone.

Enough water was encountered in the excavation for wetting the bank and for use in making mortar and concrete.

The work of putting the concrete in place began July 14 and ended July 28.

About 100 cubic yards of concrete were used in the roof, and a saving of about $700 was made by using concrete instead of brick.

After the last concrete had been in place fourteen days the wooden centering was removed and the roof found to be hard and smooth, and no cracks or settlements could be detected. As the water in the reservoir is above the freezing point, and as there is a covering of from 2 to 3 feet of earth over the top, there can be no action of the frost upon the concrete, and it should last indefinitely.

At the center is a ventilator consisting of an 8-inch cast iron sphere perforated with $\frac{1}{4}$-inch holes.

Entrance to the reservoir is had through a 26-inch manhole in the roof, on the top of which is placed a heavy cast iron cover secured by a padlock.

The soil on the top and sides of the reservoir was seeded to grass to protect the bank from being washed by the rains.

A 6-inch vertical overflow pipe connected with a waste pipe of the same size prevents the reservoir being overflowed. The top of this pipe determines the high water level of the reservoir.

Water can be withdrawn from the reservoir by the 14-inch main only to within 6 inches of the bottom at the center. All below that level must be drawn out through the 6-inch waste pipe, which can be done by opening a 6-inch gate in the bottom of the reservoir. This arrangement prevents any sediment from entering the distribution system. The 6-inch waste pipe passes through the bottom of the reservoir with a slight inclination and comes to the natural surface of the ground a few hundred feet below the reservoir.

On account of the large amount of ground water in the soil at the reservoir location a hole was made in the 6-inch cast iron waste pipe, so that it acts as a drain for reducing the level of the ground water under the reservoir and prevents any upward pressure on the bottom when the reservoir has been emptied. There is also a 2-inch composition pipe set vertically in the concrete bottom, making direct connection between the space under the concrete bottom and the reservoir. This pipe is about 1 foot long, and at the top has an elbow and on it a check valve opening toward the reservoir. In case the water in the reservoir is drawn lower than the outside ground water this check valve will open and the ground water flow into the reservoir, so that no pressure can be exerted on the concrete bottom.

An underdrain composed partly of 4-inch Akron pipe, laid with open joints and partly of broken stone, is laid on the inside of the masonry wall and just below the under side of the concrete bottom. This collects the ground water and brings it near the point where the 6-inch cast iron waste pipe passes through the wall.

The sides and bottom received carefully applied plaster and brush coats of Portland cement, and the reservoir is practically watertight.

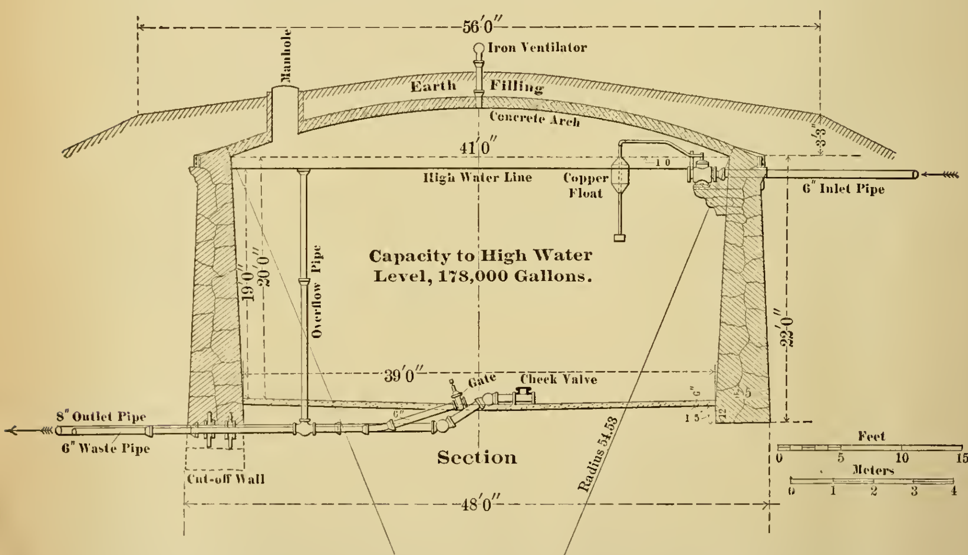
The cost of the reservoir is shown in detail by a copy of the final estimate of the contractor, Mr. Thomas Hennessey, Holden, Mass.:

3472.6	cubic yards of earth excavation	@ $0.55	$1,909.93
352.0	" " rock "	@ 1.50	528.00
643.5	" " local rubble masonry	@ 4.50	2,895.75
69.0	" " Fitzwilliam rubble masonry	@ 5.50	379.50
3.4	" " Fitzwilliam rubble pier foundations	@ 16.00	54.40
316.9	lineal feet of 14-in. pipe laying	@ .25	79.23
285.2	" " " 6 " " "	@ .25	71.30
27.7	cubic yards Portland cement brickwork	@ 18.88	498.60
16.6	" " American " "	@ 18.88	498.60
81.1	" " American cement concrete on bottom	@ 5.00	405.50
98.8	" " Portland cement concrete on roof	@ 8.00	790.40
464.2	square " Portland cement plaster coat cn sides	@ .25	116.05
411.0	" " Portland cement finishing coat on bottom	@ .25	102.75
217.0	lineal feet of drain in bottom	@ .12	26.04
204.0	cubic yards of borrowed earth	@ .55	112.20
			$8,218.65

Had there been no ledge in the bottom the cost would have been reduced $446.60, making the total expense $7772.05.

RESERVOIR FOR THE MASSACHUSETTS HOSPITAL FOR EPILEPTICS, MONSON, MASS.

This reservoir is a circular masonry structure covered with a dome or roof of concrete. It is 39 feet in diameter at the bottom



Circular Distributing Reservoir, at Monson, Mass., for Massachusetts Hospital for Epileptics.

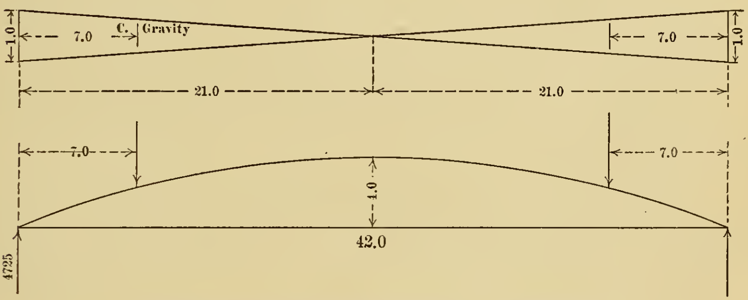
and 41 at the springing line of the roof, 20 feet above the bottom. High water level is at elevation 659.77 above sea level, and 1 foot below the springing line of the roof.

When full the water is 19 feet in depth, and the reservoir contains 178,000 gallons.

It is located about 2800 feet southwest of the hospital buildings. The elevation of the natural surface of the ground at the center was 656.2. Before making the final location a number of test pits were dug in order to decide where the least rock would be encountered. At the point selected, the ledge was 7 feet below the surface at the center, and at the bottom the entire excavation was in rock.

The excavation made was 3 feet greater in diameter than the outside diameter of the reservoir, or 51 feet. The bottom of the wall, except at the point where the 8-inch outflow and 6-inch waste pipe enter the reservoir, is at elevation 638.7. At the point mentioned the wall is several feet deeper, in order to properly surround these pipes.

The wall is 4.5 feet thick at the bottom and 2.5 at the top. It is built of rubble masonry laid in mortar composed of one part



DETERMINATION OF DIMENSIONS OF STEEL BAND.

of Hoffman cement and two parts of good sand. A portion of the stone came from the excavation and a portion from a ledge opened by the contractor on the reservoir grounds. Some stone was also brought from the Flynt quarries.

When the rubble masonry wall had been carried to an elevation a little below high water level a band made of two plates of soft steel, each 12 inches in width by $\frac{1}{2}$ inch in thickness, was riveted together in place on blocking, so as to inclose the wall when completed. The band was 46 feet in inside diameter, and made of ten plates about 29 feet in length. The plates break joints and have a splice plate on each side. That on the continuous side is 24 x 12 inches by $\frac{1}{4}$ inch in thickness. That on the other side is of the same size, but $\frac{1}{2}$ inch in thickness. Each joint has twenty-six rivets $\frac{7}{8}$ inch in diameter. There is a rivet every 3 feet between the joints.

One coat of boiled oil was applied at the shop and two coats of red lead after the band was in place.

After the paint was dry the wall was completed inside of the band, and the band inclosed in masonry or concrete to protect it from rusting.

The band was furnished in place by Edward Kendall & Sons, Cambridge, for $248, they being the lowest bidders.

The object of the band is to resist any thrust caused by the action of the concrete roof.

The dimensions of the steel band were determined as follows: Two radial sections of the concrete roof were assumed as shown in diagram, the width of the wedge-shaped piece being 1 foot, as measured along the circumference of the masonry wall. The average weight of the concrete roof, including the earth covering, snow, etc., was assumed to be 450 pounds per square foot.

The load for this radial section would be $\frac{21 \times 450}{2} = 4725$ lbs.

The resultant acts at the center of gravity of the section, or 7 feet from the inside of the masonry wall. The moment about the point of support would be $4725 \times 7 = 33{,}075$ pounds.

This moment is equal to a horizontal moment consisting of the horizontal thrust on the section, multiplied by the rise of the roof, or $\frac{4725 \times 7}{4} = 8268$.

This pressure acts upon each section of the band 1 foot in length.

The circumferential stress on the steel band at any point would be $\frac{8268 \times 42}{2} = 173{,}628$ pounds.

Assuming 15,000 pounds per square inch as a safe stress to which to subject the steel band, the area of the cross-section would be $\frac{173628}{15000} = 11.57$ square inches.

The band used is 12 inches by 1 inch, with one $\frac{7}{8}$-inch rivet hole out, giving a net area of 11.12 square inches, which is nearly the area called for.

In making this computation the tensile strength of the concrete was disregarded.

The concrete dome or roof has a diameter of 41 feet and a rise of 4 feet.

According to the specifications, either Dyckerhoff, Germania or Alsen Portland cement was to be used. The W. N. Flynt Granite Company, who had the contract, decided to use the latter brand.

The concrete is 10 inches in thickness at the springing line, and decreases to 8 inches at the center. It was put in place on accurately and thoroughly built wooden centering, covering the entire reservoir. The centering was supported on large chestnut posts, which rested on a set of hardwood wedges, which were driven out when the centering was removed. The boarding of the center was of good quality planed spruce, tongued and grooved.

The concrete was composed of one part, by measure, of Alsen Portland cement, two and one-half parts of good sand and four and one-half parts of broken stone, not over 2 inches in its longest diameter.

The concrete was thoroughly mixed as dry as could be well rammed, and put in place as quickly as possible. The amount required for the roof was about 40 cubic yards.

The work was begun about 10 o'clock A.M. November 4, 1897, and completed at noon of the next day, or in twelve working hours.

As soon as the concrete had begun to set it was covered with 5 or 6 inches of earth to prevent freezing. Afterwards about 2 feet of soil was put on in the center, increasing to about 3 feet at the circumference. An embankment was also built about the part of the masonry wall above the natural surface of the ground.

On December 3, 1897, the wedges under a number of the posts supporting the centering were removed. There appeared to be no settlement of the concrete roof. On December 24 the entire centering was removed. The concrete roof appeared hard and smooth. No settlement occurred, and no cracks could be discovered.

The masonry wall was then carefully pointed up, and a ½-inch plaster coat composed of equal parts of Alsen Portland cement and sand was put on. The object of the plaster coat was to make the reservoir as nearly watertight as possible. Later the wall was gone over with a brush coat of neat Portland cement in the form of a thin paste.

In building the masonry wall great care was taken to leave no voids and to have a wall of solid stone and mortar, preferably with as much stone and as little mortar as possible and still have all the joints filled. No stone was allowed to extend entirely through the wall, as this would form a continuous joint through the wall along which the water might escape.

At the point where the 8-inch outflow pipe and the 6-inch waste pipe enter the reservoir the wall is carried somewhat deeper, and is carefully built under and around the pipes. Cast iron flanged sleeves are secured to both pipes by a lead joint at the

center of the wall, to prevent the water following the outside of the pipe through the wall.

On the 6-inch waste pipe, nearly under the manhole, is a 6-inch T, in which is placed a 6-inch pipe with the upper end at high water level. On the inner end of the 6-inch waste pipe is a 6-inch gate. This gate is closed except when draining the lower part of the reservoir. The outer end of the waste pipe comes to the natural surface of the ground about 170 feet from the center of the reservoir.

Considerable ground water was found in the reservoir excavation. In order to relieve the bottom from an upward pressure when the reservoir is empty, the bottom of the excavation was underdrained by placing a layer of broken stone over the top of the ledge. By means of 4-inch Akron drain pipe the ground water is brought together under the concrete bottom and passes through the footing course of the masonry wall and out to the natural surface of the ground through a 4-inch cast iron pipe. Even in the dryest weather there will be some flow from this pipe, but it is in no sense due to leakage from the reservoir. It is the natural ground water which accumulates around and under the reservoir, and runs off through the drain.

Outside the reservoir is a 4-inch gate on the 4-inch cast iron drain pipe. By closing this gate the flow of the ground water from around and under the reservoir is checked, and it will rise to such a level outside of the reservoir wall that it will escape at some point.

If the reservoir is emptied when the outside water is above the level of the bottom, as before mentioned, there will be an upward pressure on the bottom, which will tend to push it in. As the area of the bottom is 1195 square feet, the total pressure would be considerable. If the outside water stood 4.6 feet higher than the bottom the upward pressure would be 2 pounds to each square inch, or a total upward pressure of 172 tons. The concrete bottom is 1 foot thick, and if the weight of the concrete is called 140 pounds per cubic foot it will by so much reduce the upward pressure of the ground water, and the net upward pressure would be about 88 tons.

It is probable that the ground water will stand at a higher level than that mentioned.

If the 4-inch gate is closed the ground water will form a water jacket to a certain height and lessen the tendency, if any, to leakage from the reservoir.

To relieve this upward pressure when the reservoir is empty and the 4-inch gate on the 4-inch cast iron drain pipe is closed two

2-inch composition pipes, with check valves similar to that mentioned in connection with the Winchendon reservoir, are provided.

The cost of the reservoir was $5644.08, as shown by the following copy of the W. N. Flynt Granite Company's final estimate. To this should be added the $248 paid for steel band:

820.0 cubic yards of earth excavation, in reservoir.....@	$0.50	$410.00
693.1 " " " rock " " " .....@	2.00	1,386.20
40.0 " " " earth " " pipe trench, within 15 feet of reservoir...@	.50	20.00
32.7 " " " rock excavation in pipe trench, within 15 feet of reservoir...@	2.00	65.40
426.1 " " " rubble masonry in Hoffman cement ....@	5.50	2,343.55
39.8 " " " Alsen Portland cement concrete, in roof ....@	12.50	497.50
3.2 " " " same, enclosing steel band, and in cut-off wall ....@		40.00
48.5 " " " " on bottom and around pipes..@	6.00	291.00
0.5 " " " American (Hoffman) cement brick masonry ....@	8.50	4.25
293.2 square " " Portland (Alsen) cement plastering on wall.................@	.35	102.62
835.3 cubic " " borrowed earth ....@	.35	292.36
39.0 lineal feet " 8-inch cast iron pipe laying........@	.80	31.20
60.0 " " " 6 " " " " " ....@	.80	48.00
47.7 cubic yards of broken stone about under drain and on bottom ....@	1.87	89.20
137.0 lineal feet of 4-inch cast iron pipe laying (under drain) ....@	.15	20.55
15.0 lineal feet of 4-inch Akron pipe, laid, for under drain ....@	.15	2.25
		$5,644.08

If there had been no rock excavation the cost would have been $4263.02, making a reduction of $1381.06.

From his experience and observation, the writer believes that concrete can be used with entire satisfaction as a covering for reservoirs, and at less cost than brick.

If the reservoir is circular the entire centering should be put in place before any concrete is used. If the covering is of brick it is often possible to remove the centers before the whole roof is completed and use them in building another section of roof.

LOCKS AND LOCK GATES FOR SHIP CANALS.

By Henry Goldmark, Member of the Detroit Engineering Society.

[Read before the Society, March 24, 1899.*]

The problems of canal construction as a part of the civil engineer's work have within recent years assumed new and unexpected prominence. Several important canals for a navigation of the first class have lately been completed, and further projects of unparalleled magnitude are now under construction or the subject of serious discussion.

Among the large works recently finished abroad may be mentioned the Manchester, the North Sea-Baltic and the Corinth canals and the enlargement of the canal prism at Suez and Amsterdam. In America the most important waterways under construction or survey are the great drainage canal at Chicago, now nearly finished; the rival projects at Panama and Nicaragua, and the equally important plan for a canal of the first class connecting the Great Lakes with tidewater.

All this activity is the more striking because for more than a generation the rapid development of railroads appeared to have given a death blow to new canal construction, and many existing canals had suffered a decrease in their traffic or had been entirely abandoned. There were, however, good reasons for this temporary decline, which was not due to any inherent weakness in canals as such, but rather to a mistaken public policy by which their great advantages were not properly made use of. The superior economy of transportation by water with vessels of proper design and in waterways of considerable size is not open to question. The modern freight steamer on the high seas and our own Great Lakes carries freight at a cost much less than even the lowest railroad rates. The tonnage of the lake traffic particularly has of late years advanced by leaps and bounds.

It is perhaps impossible to reach the same high degree of economy in the case of canal and river channels, which are necessarily more restricted. But in canals of large cross-section, using modern vessels propelled by power, the cost per ton mile should not be much greater than in open water. The real reason why our canals have decreased so much in relative importance lies in the fact that in size, in construction and especially in the nature of the

*Manuscript received April 14, 1899.—Secretary, Ass'n of Eng. Socs.

boats used on them, they are many years behind the times, and represent a phase of development long past in all other departments of transportation. When operated in competition with the highly developed railway systems, embodying the latest improvements of modern engineering, it is not to be wondered at that they have lost most of their former importance.

The only way in which canal navigation can be revived is to put it as nearly as feasible on the same footing as navigation in lakes and large rivers, by using large vessels, equipped with modern machinery, in channels of sufficient cross-section to keep the resistance to the movement of the vessels within economical limits. It goes without saying that canals of this description are very expensive to construct and maintain. There will, therefore, be but few locations on which the volume of the traffic will be sufficient to warrant their construction, and we may expect that but few canals will be built in the future, but they will be works of strictly the first class.

To the constructing engineer canal building offers many problems of great interest. The location of the canal, both from a commercial and a strictly engineering standpoint, requires careful study, while the excavation of the channel offers a field for introducing new and ingenious methods for handling earth and rock work on a large scale. The hydraulic questions involved, such as seepage, evaporation, problems of water supply, the flow of water in open channels, etc., are all interesting as matters of theory, and offer a rich field for experimental research.

In this paper it is not proposed to take up any of these topics, but to confine it to the subject of canal locks; not only because they are the most important structures in canal construction, but also because they have not been adequately treated in American engineering text-books.

GENERAL DEFINITIONS.

A canal lock may be defined as a structure which enables vessels to pass from a body of water to an adjacent one which is at a different level. As usually built, it consists of an enclosed basin or chamber provided with gates by which it may be shut off at either end, so that it can be put in communication alternately with the upper and lower levels. The method by which boats are passed through a lock is simple and readily understood.

Besides the ordinary canal lock, various other means for overcoming diffeıences of level in canals have been proposed at different times for at least one hundred years past. Among these may be

mentioned inclined planes and mechanical lifts acting vertically. A few inclined planes have been in use on small canals both in America and Europe for many years. Of vertical lifts a large number of projects have been worked out on paper, but only four of these have been built and are now in use. They are the hydraulic lifts at Anderton, England; Les Fontinettes in France and La Louvière in Belgium, and the floating lock, so called, at Henrichenburg, in Prussia. The largest of these is the last-named, which is 230 feet long by 28 feet wide, with a draft of water of 8 feet. The amount of lift is 52½ feet.

The operation of these lifts, the oldest of which has been in use for over twenty years, is quite satisfactory. Their principal *raison d'être* is the saving in water which they accomplish as compared with ordinary masonry locks. They are certainly of much interest, and in special locations their use will probably be more general in the future. The locks are, however, at best the most vulnerable portion of a canal system, and engineers may well hesitate before putting a more complex mechanism in place of the simple and massive masonry lock.

HISTORY.

The invention of the canal lock is one of the few great discoveries by which civilization has been measurably advanced. It alone has made it possible to navigate many important rivers and to carry canals over considerable elevations where a *single level* canal would be out of the question. The credit for building the first lock is claimed by both Holland and Italy, but the evidence as to time and place is conflicting. While in the plains of Northern Italy the navigable canal is the outgrowth of the shallow irrigating ditches used from time immemorial, the Dutch canal for boats has developed from the channels required to drain the low-lying fields or polders. In both countries simple sluices or head gates were built long before the enclosed lock with enclosed chambers. Such gates are sometimes used for navigation, and are often confounded with true locks by the earlier writers. The first clear and distinct description of a lock with an enclosed chamber is said to have been given by Leona Battista Alberti in his book entitled "De re. Aedificatoria," a copy of which was presented to the Pope Nicholas V in 1452. Simon Stevinus, the celebrated Dutch scientist, also gives a good account of a canal lock in a treatise published in 1618.

By other writers it is claimed that the first lock was built in 1481 near Padua, in Italy, while the advocates of Dutch priority feel confident that true canal locks were in use in the Netherlands before 1250. It may be added that the common canal lock is fre-

quently called the *Visconti* lock, from its alleged inventor, while by others the laurels of Leonardo da Vinci, already so ample, are increased by ascribing the discovery to the great painter. The exact date is, of course, not very important. It is of interest, however, to note that lock building, as well as canal construction generally, antedates the establishment of our profession by several centuries. In hydraulic works of all kinds many successive generations had accumulated a large amount of practical experience long before the civil engineer, as such, had come into being. In canal work a high degree of perfection was reached at least 150 years ago. Faulty methods in construction and operation had been gradually eliminated by the severe test of time and experience, so that the forms then in use have been followed pretty closely, as least for small canals, down to the present day.

Within the past fifty years many large locks have been built, but the principles of their construction are essentially the same as those followed in the older and smaller works.

Although the ordinary canal lock has often been criticised on various grounds, it cannot be denied that it has proved itself in practice an extremely satisfactory piece of mechanism. It is simple and durable, requires few repairs and is inexpensive in operation.

CLASSES OF LOCKS.

According to their location, locks may be divided into two general classes: (1) locks in inland canals and canalized rivers; (2) locks in maritime canals and harbors.

In the first class the difference of level to be overcome is due to the configuration of the ground, which makes it necessary to divide up the waterway into a series of pools or reaches at different levels. The "lift" in this case is practically constant, and the water pressure against the gates of the lock always acts in the same direction.

On the other hand, in locks used in harbors and in canals communicating with the ocean the difference of level is due to the tides, and in certain cases to wind action. In the North Sea-Baltic canal, for instance, there is a complete lock at the east end of the canal which is in use only about twenty-five days in the year,—at times when a strong east wind from the Baltic piles up the water in the outer harbor.

The principal use of locks in harbors is for closing dock entrances where the range of the tides is considerable. This is the case on the coasts of England and Germany, and on the Atlantic coast of France. The difference between high and low tide is rarely less than 15 feet, while in some localities, such as the ports in

the Bristol Channel, it reaches 44 feet at certain times in the year. In these harbors vessels are loaded and unloaded in enclosed basins surrounded by quay walls, in which the water is kept approximately at a constant level. These basins have narrow entrances, closed by one or more gates. In some of the docks, especially those of earlier construction, there is no enclosed chamber, so that the lock reduces to a mere pair of gates in the entrance channel. These gates are open for an hour or so at high tide, and all vessels must pass in and out at this time. When the tide in the outer harbor begins to fall the gates are closed, and keep the water in the dock basin from running out. In order to provide against exceptionally high tides in the outer harbor, another pair of gates is usually added, which are built so as to support water pressure acting from the outside. A further modification where the range of tide is great is the introduction of a "half-tide lock" with a second pair of gates, so that the pressure on each of them is reduced.

The limited time to which the traffic is confined in this form of dock entrance is objectionable, and many modern English docks are provided with complete locks having enclosed chambers, so that vessels can be locked through between the outer harbor and the docks at all hours. At high tide the gates are left open for some time, and the larger vessels usually come into the dock without locking.

The construction of these harbor locks is almost identical with the locks on large ship canals. In the leading ports of Great Britain a large number have been built during the last fifty years. In Liverpool alone there are more than one hundred pairs of lock gates for openings varying from 40 to 100 feet. As but few large ship canals have so far been built, it is to the experience gained in building these large dock gates that we must mainly look for guidance in designing similar works.

DIMENSIONS.

In designing a complete canal lock the first points to be fixed are the proper dimensions. These are the width, the length, the depth of water on the sill and the lift or difference of level between the water above and below the lock.

The width and length and the depth on sill are commonly the same for the whole canal, and depend on the maximum size of vessel employed. On the canal proper it is necessary to make the prism very much greater than the cross-section of the vessel, say from four to six times as great, so as to reduce the resistance to motion through the water to an economical amount. In the locks

this is unnecessary. An excessive size involves waste of water, increases the time required to operate the lock and greatly increases the first cost. In some cases, where the traffic is very heavy, locks have been built wide enough to allow two ordinary vessels to be docked side by side, and long enough to take in several of them one behind the other. The new American lock at Sault Ste. Marie, which is 100 feet wide and 800 feet long, is a so-called "fleet lock" of this kind. The wisdom of this design is doubtful. As the width and length of lake vessels is constantly increasing, it will not be very long before all the older and smaller vessels will go out of service, so that the 100-foot lock will not be wide enough to take in two of the vessels side by side nor long enough to allow them to enter "tandem." In that event the large dimensions of the lock will be worse than useless. The Canadian lock at the Sault, finished in 1895, is only 60 feet wide, but 900 feet long, and appears better adapted to the demands of traffic.

The probable size of vessels in the future is not easy to foresee, and the dimensions to be adopted for designing locks for large ship canals will vary greatly, according to individual judgment. Some thirty years ago the largest vessels were steamers with paddle wheels that projected a considerable distance on either side of the hull proper. To provide for these several locks 100 feet wide were built in the Liverpool and Havre docks. These are now wider than necessary. At present few merchant vessels are wider than 60 feet, although a few of the largest exceed this limit, and the "Friedrich der Grosse" is 68 feet wide. War vessels have somewhat greater beam, the "Iowa" of the United States Navy being 76 feet wide over all.

The locks on the North Sea-Baltic canal are 82 feet wide, while the new locks at Bremerhaven are to have a clear width of 92 feet, in accordance with a request of the North German Lloyd Steamship Company. On the Manchester canal 80-foot and 65-foot locks are used, although a still narrower lock is built at the side for small craft.

The proposed locks for the new Panama canal are to be 59 and 82 feet wide, and about the same width will probably be adopted at Nicaragua.

The depth of water on the sill of the lock should equal the maximum draft of the boats, with an additional clearance of $1\frac{1}{2}$ to 2 feet.

The "lift" of a lock is its most important feature. If the width may be compared to the "length of span" in a bridge, the lift is analogous to the loading to which the bridge is subjected. The

lift or difference of level is fixed by topographical configurations, though in many cases the location of the canal is affected by the amount of lift which can safely be used. The inferior limit of the lift in a lock may be 1 foot or even less. The upper limit has not yet been reached. Very few locks with lifts exceeding 20 to 25 feet have ever been built. The greatest lift known to the writer in an inland canal lock is 30 feet. This lift is used at the new locks in the St. Denis canal, in France. In the Avonmouth dock at Bristol, England, the range of the tide is nearly 44 feet, and the strength of the gates is calculated for a head of 45 feet. This lock was built nearly thirty years ago, and though the gates are of timber their operation has been entirely successful.

The question whether lifts as high as 40 or 50 feet are advisable must be studied carefully for each separate case, and will depend on the supply of water, the density of traffic and other considerations, as well as on the structural difficulties involved. During the past year the writer has been engaged in the design of locks of various lifts up to 50 feet. So far as his plans have been matured, they show no reason why lifts of 45 or 50 feet could not be successfully used on locks as wide as 80 feet.

Such great lifts will seldom be needed, as the topography of the country passed through is almost always such as to make the majority of locks of moderate lift. Even where a concentration of the locks at a few points might otherwise be advantageous, this can rarely be done without flooding too large an area of valuable land. For this reason the opinion sometimes expressed that the adoption of mechanical locks which permit the concentration of the lift at a few points will always result in economy is a mistaken one.

CONSTRUCTION OF THE LOCK WALLS.

The construction of a lock may be divided into three parts: (1) the foundation, the side walls and the floor, which are generally built of masonry; (2) the culverts and valves for filling and emptying the lock, with the mechanism for operating the valves; (3) the lock gates and the machinery for moving them.

As in most structures, the nature of the foundation encountered affects the difficulty of construction to a high degree. Fortunately, in inland canals the locks can often be located on a solid rock bottom. In the case of harbors, on the other hand, rock is rarely encountered, and in many cases the bottom is extremely soft. The successful operation of the gates requires that the side walls and sill should remain almost absolutely true to their original lines. The difficulty of securing this result is greater than that encoun-

tered in building an ordinary quay wall. No general directions can be given as to the best choice of foundation in any given case. When the bottom consists of a rather firm sand or clay it is usual to cover the entire site with a layer of concrete of sufficient thickness to support the upward thrust of the water which may tend to lift it. This layer of concrete is laid in the dry when this is feasible, but must usually be deposited under water. The side walls are built on this foundation, and the portion between the walls forms the floor of the lock. When the bottom is softer and more variable piling must be resorted to, at least under the side walls, so that the weight of the walls may not tend to crack the floor. The problem of dimensioning the side walls and the floor when the bottom is soft is extremely complicated.

When built on solid rock a lock wall can be designed according to well-understood rules in the same way as a retaining wall. Each wall acts separately, and its weight is carried by the rock bottom immediately below it. The forces tending to overthrow the wall are the earth pressure behind it, to which must be added a certain amount of water pressure, varying with the permeability of the back filling. In this calculation the lock is, of course, supposed to be empty and the ground water to stand at its highest level.

When designing a lock to be built on a soft bottom we cannot calculate the strength of each wall separately, but must consider the entire cross-section of the lock—*i.e.,* the two side walls and the concrete floor—as a whole. This section is subjected to a variety of forces,—viz, the earth and water pressure on the side walls, the upward pressure on the bottom of the floor and the walls, besides the weight of the masonry and of the water in the lock. The magnitude and distribution of the upward reaction of the bottom cannot be exactly estimated. It is possible, however, to make a graphic analysis and draw a line of pressures in the walls and floor under various hypotheses. By comparing the conclusions to be drawn from this analysis with practical experience in locks built on a soft bottom much assistance can be gained in proportioning new structures. With the usual proportions the line of pressure at the middle of the floor is quite eccentric. This shows the existence of a considerable bending moment, which would tend to crack the floor at the top. Such longitudinal cracks have actually occurred in a number of harbor locks at the very points indicated by the theoretical analysis. They are not necessarily of a destructive character, and after they have been closed with concrete are not likely to give much further trouble. The structure after fracture is in a new position of equilibrium corresponding to a new distribution of pressure on the bottom.

Laying concrete under water is always somewhat unsatisfactory. In building the large locks at Holtenau, on the North Sea-Baltic canal, a simple but elegant method was used for lowering the ground water level and excluding the water from the lock pit. Three wells 12 feet in diameter were sunk by compressed air to a depth of about 15 feet below the bottom of the pit. They were placed close to and just outside the lock at three of its corners. By pumping from these wells with centrifugal pumps for a period of fifteen months the water level over the entire lock was lowered so that the foundation could be built entirely in the dry.

Compressed air caissons and open wells sunk by dredging have also been used for the foundations of harbor locks. The method used is practically the same as that employed for bridge piers. The locks at Toulon, Dieppe and some other French ports were built with compressed air foundations, while the Bordeaux lock was founded on open wells. In the latter case the close proximity of large warehouses was the reason for choosing this method.

The material used in lock walls is almost always masonry, but floors of timber construction are not unusual, even in large locks. Cut stone masonry is generally employed, though rubble with an ashlar facing is not uncommon. Of late years some locks have been built entirely of concrete. Among these are the fine locks recently completed by the United States Government on the Hennepin canal in Illinois. The writer has also had occasion to examine the masonry recently built for the new guard gates in the St. Mary's Falls canal. This masonry consists of a rich concrete without any cut stone, and presents a very good appearance. The gates are of timber, and span a clear opening of 108 feet. This is a greater width than any known to the writer elsewhere.

The masonry at the ends of a lock must support the pressure from the gates. The walls at the ends are necessarily thicker than the side walls of the chamber, and must be built with extreme exactness, so as to fit the gates. Their details will depend on the style of gate used.

The construction of the masonry is further complicated by the necessity of inserting culverts for the filling and emptying of the lock, and also of tunnels for the cables that move the gates and the pressure pipes connected with the operating machinery.

ARRANGEMENTS FOR FILLING AND EMPTYING THE LOCK.

Three different plans are in use for this purpose: (1) valves in the upper gate; (2) side culverts in the lock walls; (3) culverts under the floor of the locks.

The first plan has the merit of simplicity, and is generally used in small locks. The openings are rectangular and placed as low as possible in the gates, so as to act with the largest possible head. The valves are simple sluice gates, operated by hand from the top of the gate. Such openings weaken the gate where the water pressure is greatest. Another objection is the fact that the water rushes in with much velocity, and tends to break the cables of vessels in the lock. Furthermore, the time required to fill a large lock by valves in the gates is excessive. For this reason such valves are supplemented or replaced in most large locks by culverts in the side walls or under the floor. The latter arrangement can be conveniently adopted only in case of a rock foundation, to which the floor system can be bolted down to resist the upward pressure of the water, tending to lift the floor when the culverts are filled. The most important examples of such culverts are found in the three great locks at Sault Ste. Marie. In all of these the water is admitted through large rectangular culverts under the floor. They are about 8 feet square, and connect with the lock chamber by a large number of openings along the bottom of the lock. The culverts run side by side, and are built of solid timbers. There are two culverts in the smaller American lock, six in the larger and four in the Canadian lock. The head is about 19 feet. The largest lock is filled in about eleven minutes, using four culverts only.

Side culverts are general in the larger European locks, such as those in the Manchester and North Sea-Baltic canals. There is a culvert in each wall about twice as high as it is wide. In the Manchester canal the size of the culverts is 6 x 12 feet. They discharge into the lock by lateral openings.

In connection with culverts three classes of valves are used,—viz, slide valves, butterfly valves and cylindrical valves. The first class are rectangular, and may be built of either metal or wood. It is desirable that they should move with little friction, and be as nearly water-tight as possible. On the Manchester canal the Stoney sluice gates are very successfully used, in which the friction is largely reduced by a system of roller bearings. In the North Sea-Baltic canal a similar sliding gate built of timber was adopted. In American locks butterfly valves revolving on a central axis are common. They are simple in design and durable, and require but little power to operate them. The only objection to their use is the excessive consumption of water, as they cannot be made with a tight fit. This precludes their use where water is scarce.

Cylindrical valves are in use on many French canals, and have been proposed for the enlarged Erie canal. They consist of vertical

steel cylinders resting on conical seats, and are raised vertically to admit the water through an annular orifice.

While these valves have many good features, they are quite expensive, as the amount of water that can pass through any one valve is comparatively small. Valves are generally operated by power, the machinery being combined with that for moving the gates.

LOCK GATES.

Although they represent a relatively small part of the total cost, the gates are more complex in construction than any other part of the lock, and on their correct design its successful operation will largely depend. Considered merely as structures, they present an interesting field in the theory of stresses and in practical designing.

Every lock with an enclosed chamber must have at least two gates,—one at each end. Besides this an intermediate gate is frequently added, which permits the working length of the lock to be shortened so that smaller vessels can be locked through more quickly and with less waste of water. Quite generally, too, a guard gate is built at either end to allow the entire lock to be laid dry for periodic examination and repair.

Lock gates, whatever their detailed design, are really movable dams, and when closed support the pressure of a considerable head of water. The standard form used in the great majority of cases is the mitering gate. This consists of two leaves, each turning on a vertical axis, like an ordinary door. When closed the leaves meet at an obtuse angle, the so-called toe posts abutting against each other in the middle of the lock, while the bottom of the gate rests against a continuous sill. When in this position the two leaves act as an arch which conveys the water pressure to the side walls. The fitting of the gates against each other and the sill is difficult to make and maintain uniform at all times. A bad fitting may interfere with the proper working of the gates, and also causes the stresses in the different members to be somewhat uncertain.

For these reasons, among others, many substitutes for mitering gates have been proposed, and some of them carried into execution. The more important of these forms may be briefly referred to.

(1) The single leaf revolving gate. This consists practically of one leaf of a mitering gate long enough to reach across the lock at right angles; the gate is supported on the bottom and both sides, and acts as a girder or truss instead of an arch. The single leaf is, of course, heavier than the separate leaves of a mitering gate for the same opening. It requires much more power to move, and also

shortens the available length of the lock which can be occupied by vessels. The cost is about the same as for double-leafed gates. Single-leafed gates have of recent years been built in France up to 50 feet in length.

(2) The "Tumble" gate, which also spans the canal with a single leaf, but revolves on a horizontal shaft fixed at the bottom of the lock. This form has been used in some of the Erie canal locks for many years.

(3) Sliding gates. Gates of this kind have been built in different English and continental harbors, and in this country in connection with the Davis Island dam in the Ohio River improvement. The foreign gates are of iron with closed air chambers, while the Davis Island gate which spans an opening of 110 feet is of timber framing. These sliding gates when closed act as trusses, supported by the side walls and the sill. They are opened by moving them sideways at right angles to the lock into a recess constructed in the masonry wall on one side.

(4) Pontoons. Pontoons are sometimes rectangular gates like the sliding gates just referred to, although they may also be built having the curved outlines of an ocean vessel. They are floated across the lock entrance, and are sunk into position by letting water into tanks provided for the purpose. When the lock is to be opened they are moved into recesses in the wall. Pontoons are used generally in dry docks, but are not well adapted for ordinary canals where rapid and frequent moving of the gates is required. The same may be said of the sliding gates, although the latter, if properly designed and fitted with a good moving mechanism, would probably give satisfaction in canal work.

The ordinary mitering gate has, however, in the writer's opinion, so many strong points, such as lightness and facility of movement, that it is likely to hold its own even for large locks.

MITERING GATES.

Mitering gates are built of all sizes, from the great gates spanning openings of 100 feet down to the smallest guard gates. The material used in their construction is timber or iron, or a combination of the two. For small gates timber is in every way preferable, as the first cost is less, repairs are more easily made and there is no difficulty in designing gates of simple construction using timbers of small scantling and length. A number of small iron gates have been built in different countries, but the prevalent opinion among the engineers directly in charge of canals seems to be averse to their general adoption.

The general use of steel in bridges and ships makes large wooden lock gates seem somewhat out of date. Metal would appear to have great advantages as in other engineering structures. Large iron gates have, as a matter of fact, been in use for over fifty years, the first wrought iron gate having been built for a 60-foot dry dock entrance in the Brooklyn Navy Yard about 1850, while about the same time similar gates were constructed by English engineers at Sebastopol, Russia, and by the Germans in the Bremerhaven docks. It has never been denied that these and later iron gates have given perfect satisfaction.

It is true, nevertheless, that many English and American engineers of great experience in lock work remain strongly prepossessed in favor of timber gates. In England, even at the present day, about half of the new gates are built of wood. In the Manchester canal green heart timber, a very durable wood brought from British Guiana, was used exclusively in the fifty-four gate leaves built, although the cost was much greater than that of iron gates would have been. Some of the large American gates, such as those in the new Canadian lock at the Sault, are also built of wood.

Apart from natural conservatism, the reasons which make for wooden gates are their greater lightness, which makes them easier to move, and still more the ease with which they may be repaired in case of a collision. Such accidents are always possible, although they are rare. It does not seem to the writer that this contingency is sufficiently probable to make it wise for us to give up the great advantages of steel gates.

DETAILS OF CONSTRUCTION.

A mitering gate consists of a skeleton or *frame* and a *watertight* sheathing. The frame may be arranged in different ways, but there is always a heel or quoin post close to the masonry, a toe or miter post at the other end of the leaf and two horizontal girders, one at the top and another at the bottom of the gate. Besides this there are usually a number of intermediate horizontal girders forming a series of arches or rafters carrying water pressure. In a few gates vertical girders, which bear against the top horizontal girder and the bottom sill, take the place of the intermediate horizontals. The weight of the gate is supported on a vertical pivot fastened to the bottom of the quoin post, while at the upper end of this post there is an anchorage which extends into the masonry wall. A roller traveling on a circular track on the bottom of the lock has in the past been quite generally used at the outer end of large gate leaves. This relieves the pivot and anchorage of much weight, but

makes distribution very uncertain. The disadvantages of rollers have led to their gradual abandonment.

TIMBER GATES.

The sheathing is always made of planking with calked joints. The posts consist of one large timber or may be built up of several pieces. The horizontals differ in construction according to the size of the gate. For moderate spans straight horizontals made of a single timber can be used, but for larger gates built-up trusses must be employed. Where long timbers can be had, bowstring girders with wooden tie beams, or preferably with iron tie rods, are probably the best form to be adopted. As examples of such girders, the old gates for the 100-foot dock entrances at Liverpool and Havre and the Weitzel lock at the Sault (60 feet wide) may be referred to. The gates in this last lock have been renewed during the past winter. They were designed by Mr. Alfred Noble, M. Am. Soc. C. E., and completed under his care in 1881. The iron rods, pivots, etc., were found to be in perfect condition and have been used for the new gates.

Where long timber is difficult to obtain, the horizontal girders may be built up of several short lengths framed between vertical intermediate posts and bolted to reinforcing timbers. Many English gates are built in this way.

IRON AND STEEL GATES.

Iron or steel gates, like timber gates, consist of a frame and a sheathing, both of metal. The cushions at the quoin and miter posts and the sill where water-tightness is required are usually made of wood.

The design of a steel lock gate, like that of any other structure, is largely dependent on the forces which it has to resist. These will be different when the gate is opened and when it is closed. When open, the gate exerts a horizontal pull on the anchorage, while its weight rests on the pivot. These forces must be transmitted through the gate frame and are readily analyzed.

When the gate is closed the water exerts a horizontal pressure, which is transferred by the gate to the side walls and sill of the lock. The magnitude of this pressure is easily determined, being at each point equal to the hydrostatic head. The upper gate is most strained when the lock is entirely empty. The pressure increases from 0 at the top to a maximum at the bottom, and may be represented by a triangle.

In the lower gate it is 0 at the top, increasing uniformly to the

level of the lower pool, and from that point is a constant to the bottom of the gate. It may be represented by a trapezoid.

The gate can be designed to stand this pressure in various ways. The most common form consists of a series of horizontal girders spaced in an approximately equal manner and fastened securely to the quoin and miter posts. They are further held in place by vertical frames, intermediate between these posts, which add greatly to the stiffness of the gate. The sheathing consists of plates riveted to the horizontals and calked at all joints to secure water-tightness. This sheathing is required only on one side as far as the function of the gate as a dam is concerned. It is a very general practice, however, to place the covering on both sides, forming a series of air-tight compartments, the flotation of which relieves the pivot and anchorage of weight and makes the gate easier to turn. Some of the chambers are also filled with water as ballast.

The closed chambers are hard to keep tight and somewhat inaccessible. For this reason in some of the latest designs, such as the Cascade locks on the Columbia River and the Plaquemine locks in Louisiana, both built by the United States Government, they have been omitted and the gates built with a single skin only.

In beginning the actual design, the first point to be settled is the rise of the sill, which fixes the angle which the gates make with the axis of the lock. The rise varies from $\frac{1}{3}$ to $\frac{1}{6}$ of the width in various locks, but a rise of $\frac{1}{5}$ is perhaps the best, being as economical as a greater rise.

The next point to be considered is the proper outline of the horizontals. These are almost always plate girders, and may either have a straight girder shape or else follow the lines of an arch, the medial line of which is a circular curve passing through the center of the quoin and miter posts.

Each horizontal is in equilibrium under three external forces, —viz, the water pressure, which is uniform and normal to the face of the gate, the reaction of the other leaf, which is at right angles to the axis of the lock, and the reaction of the masonry at the quoin. These two reactions are equal and make the same angle, with a line connecting the center of pressure at the quoin and miter posts.

If the gate consisted of a linear arch without thickness, a circle would be the true line of equilibrium for the forces acting on it, and the arch would be in pure compression, and hence the most economical shape. On these theoretical grounds, it has generally been held that an arch gate of circular shape is necessarily the most economical. This has been stated by many different writers for

fifty years back, and the proposition has been reinforced by many intricate calculations, involving the use of the higher mathematics.

As a matter of fact, the gates are never linear arches, but must be built as curved beams which are rarely less than 3 feet in thickness, so that the surface submitted to the water pressure is not identical with the curved axis of the horizontal girder. Furthermore, the center of contact or pressure where one leaf presses against the other at the miter post is rarely exactly on the medial line, but, on the contrary, varies considerably on either side. This difference of position is due both to unavoidable inaccuracy in fitting and material and also to the change in the length of the gate leaves at different times, owing to variations in temperature. As a result of this, the circular arch is never in pure compression, but also subject to considerable cross-bending. Besides this, in proportioning engineering structures many practical considerations, such as the minimum thickness of metal that may be used, etc., must be taken into account, so that any general theoretical deduction loses still more in value.

The only reliable method of comparison for different shapes consists in a series of estimates based on actual detailed designs. By means of several extended estimates of this kind, the writer has satisfied himself that, at least for locks up to 80 feet in width, the circular arched gate is no more economical than the straight or girder shape, while it has many practical disadvantages.

The dimensions of the web and flanges in any given girder are to be determined by the rules commonly used where there is a combination of compressive and bending stresses.

Another interesting question is the distribution of the total water pressure over the different horizontal girders. The total amount of this pressure for the whole gate is perfectly determinate. In case the horizontal girders were connected by a flexible sheathing, the distribution would be equally simple, each girder getting exactly the load due to its head below water level. As actually built, the girders are connected by sheathing that has some stiffness and by vertical posts that have much rigidity. Furthermore, the bottom of the gate fits more or less closely against a solid sill. The stiff vertical members modify the distribution of the load over the different horizontals, even when there is no contact on the bottom sill and still more when there is contact, so that the verticals carry some of the water pressure to the bottom sill. The result is that the upper part of the gate is more fully loaded, while the lower horizontals are proportionately relieved.

Some interesting experiments on models made by M. Chevalier,

in France, in 1850, illustrate this point very beautifully. The mathematical statement of these complex stresses has been attempted by several French engineers, but their methods are very intricate, and the results, while indicating correct values, hardly merit extreme confidence.

The method of "Least Work" for solving indeterminate stresses has been applied by the writer to this question with results that agree satisfactorily with some measurements he has made during the past year on the deflections of large gates.

French engineers commonly design the lower girders of their gates in accordance with the formulæ referred to above, assuming simultaneous contact at the miter post and the sill at all times, while in England it is usual to proportion each girder for its full hydrostatic head. As the close fitting at the sill is likely to fail at times, the English practice seems the safer one, though the upper part of the gate should be strengthened rather more than is customary in some of the English gates.

The details of construction in all parts of the gate will, of course, vary according to the individual judgment of the engineer in charge.

Many otherwise good gates are unnecessarily complex in construction, showing a lack of familiarity with shop practice on the part of their designers.

In lock gates, which are machines rather than structures, facility of operation and freedom from breakdowns are far more important than first cost. At the same time a gate that is simple in detail is also likely to be satisfactory in daily use.

MACHINERY FOR OPENING AND SHUTTING THE GATES.

The methods used for opening and shutting the gates can only be briefly referred to. In large modern locks the machinery is always operated by power, in order to shorten the time required. The prime movers are generally turbine wheels, operated by the water in the canal at the head equal to the lift of the lock. The power thus generated is transmitted to the mechanism for moving the gate by water under pressure, by compressed air or by electricity. In the past water under pressure varying from 100 to 800 pounds has been generally used. Machinery of this kind was first designed by Sir William Armstrong for English harbor locks, and includes the use of his well-known accumulator. Most English plants have been constructed by this firm, and designers in other countries have generally used very similar forms. The water under pressure moves reciprocating pistons to which cables are

attached, or else rotary engines, usually with three cylinders, are used.

The turning of the gates is generally effected by steel cables or chains, which are attached close to the miter post near the bottom of the gate. One cable serves for opening and another for closing. The cables are brought to the engines on the top of the lock walls through tunnels built in the masonry. The details of the attachment and general arrangement differ in various designs, but it is usual to have an independent engine on each side wall.

Although cables and chains have worked very satisfactorily, they have some disadvantages, and in several recent locks other appliances for opening and shutting the gates have been adopted; thus, in the new locks at Barry, in England, a stiff strut is used which is attached to the gate above the surface of the water, and serves both to open and shut it. One end of this strut connects directly to a plunger that moves in a hydraulic cylinder. This cylinder oscillates on a double axis, which is placed in a recess built in the wall approximately at right angles to the face of the wall. In the North Sea-Baltic canal, and also in the new lock at Ymuiden, at the west end of the Amsterdam canal, a similar arrangement is used, but the strut is not directly moved by hydraulic power, but carries a rack that connects with geared spur wheels.

Quite recently electric motors have been substituted for water pressure engines, and the use of this power is likely to become general. Hydraulic machinery in cold climates is always likely to give trouble, and in some instances it is necessary to use oil in place of water during the spring and fall before it becomes necessary to cease operating entirely. Besides this the transmission of power by pressure pipes to distant parts of the large lock involves expensive construction, and repairs are frequently needed. The use of the electric current would seem to obviate all these difficulties. In the Canadian lock at Sault Ste. Marie electric motors are used for opening and shutting the gates, as well as operating the large valves in the culverts. The operation of this machinery is entirely satisfactory, although it seems to be rather complicated.

Electric power has also been adopted for the gates of the new lock at Ymuiden, on the Amsterdam ship canal, as a result of an extended series of experiments. We may expect that in the future most new locks will be operated as well as lighted by electricity.


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MEXICO.
PACIFIC O.
ATLANTIC O.
GULF OF MEXICO
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
CAL.
NEV.
UTAH
COLO.
ARIZ.
N. MEX.
N. DAK.
S. DAK.
NEBR.
KAN.
OKLA.
IND. TY.
TEX.
MINN.
IOWA
MO.
ARK.
LA.
WIS.
ILL.
MISS.
MICH.
IND.
KY.
TENN.
ALA.
OHIO
W.VA.
VA.
N.C.
S.C.
GA.
FLA.
MD.
DEL.
MASS.
CT.
ME.
120
105
90
75
45
40
35
30

ASSOCIATION OF ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. OCTOBER, 1899. NO. 4.

THE FLOW OF WATER IN PIPES.

BY C. H. TUTTON, MEMBER ENGINEERS' SOCIETY OF WESTERN NEW YORK.

THE substance of the following paper was originally read before the Engineers' Society of Western New York, in April, 1896. There was a very glaring absurdity in it as then prepared which escaped notice until after it was ready for distribution, and the author was also taken to task by some of his critics on the charge of levity. While the present paper may be somewhat open to this charge, we shall endeavor to avoid much of that used before, confining it to our quotations.

The attempt will be made to show that the Torricellian formula, $v^2 = 2gh$, is misapplied in the fundamental stages of the science of hydraulics; and while it is recognized that the author may be wrong, he would ask, if such be the case, how can the many agreements of his deductions, which seem too numerous to be accidental, with what has heretofore been regarded as entirely within the domain of experiment, be accounted for?

Weisbach demonstrated the Torricellian theorem substantially as follows: If the head h be constant, the velocity of efflux being v, and the discharge per second being Q, w being the weight of an unit of mass, the weight of the liquid discharging will be Qw. The work which this quantity of liquid can perform while sinking through the distance h is Qhw, and the energy stored by the discharge, whose weight is Qw, in passing from a state of rest to the velocity v is $\frac{v^2}{2g}$ Qw. If no loss of mechanical effect take place during the passage through the orifice these quantities of work are equal to each other, whence we obtain $v^2 = 2gh$.

The more modern demonstration is: Suppose the head h be constant, then the potential energy of the mass is $F = mgh$. The kinetic energy of the issuing mass is $E = \frac{1}{2}mv^2$. If these be placed equal, then $v^2 = 2gh$; or, in other words, we have the remarkable result that the velocity of the issuing water through a horizontal orifice varies directly as the square root of the acceleration of gravity by *twice* the head.

From this result it can be shown that the pressure at the orifice is equal to the weight of a column of water whose area is that of the orifice, and whose height is *twice* the head. Bazin has proven this false experimentally. (See "Contraction of the Liquid Vein," Trautwine's translation, p. 32.)

That the first result is not true is shown in the simplest experiment with an orifice, the quantity discharged never being equal to the area of the orifice by the velocity as deduced by this equation.

As Mr. Robert D. Napier says (*Engineering,* Vol. XXI), "First of all a theory is adopted, which makes out that a certain amount of work should be done; then a double-headed phantom is invented to do the proposed work; then, because the work is in reality not done, it is argued that that arises mainly from the fact that the phantom is in such a hurry to do its work that it trips itself up and blocks up the orifice it is trying to get through."

The same gentleman says, in Vol. X, No. 1, of the "Proceedings of the Philosophical Society of Glasgow," "I have proved . . about three-eighths of the ultimate velocity and five-eighths of the *vis viva* is imparted to the water outside of the plane of the orifice."

M. Bazin (p. 27 of work before referred to) speaks of the rapidity with which the velocities vary from the plane of the orifice in a distance equal to its radius from it, when "they are completely equalized throughout the entire cross-section." He also says, p. 39, that "the formula $v = \sqrt{2g(h + y)}$ is no longer rigorously exact from a theoretical point of view."

Professor Heinemann (*Van Nostrand's Magazine,* Vol. VI, p. 198) attacked the theory above presented, arriving impliedly at $v^2 = gh$, this in turn being attacked by Professor S. W. Robinson, who defended the original theory. In any event, both of these require a correction usually expressed by a symbol representing the so-called coefficient of contraction, deemed essentially one of experiment, and assuming a contracted vein which Bazin states (p. 36 of work before quoted) does not exist.

Professor Hele-Shaw, in the *Engineer,* June 2, 1899, states that "it is extremely convenient to treat all kinds of resistance as following the same law,—viz, square of velocity, which the varia-

tion of head or height of surface has been shown to do. But this is far from being exact, and an enormous amount of labor has consequently been expended in finding for all conceivable conditions in actual work tables of coefficients," etc.

Now, both of these, and, in fact, all theories so far presented, imply that the mass *above* is that directly *over* the orifice, since they require a mass equal in area to that of the orifice, transferred through the height h in each element of time. Is this correct? Is not our so-called coefficient of contraction a necessity of physical laws, and susceptible of direct calculation rather than an empirical constant?

Suppose A, B be the free surface of a mass of liquid, and O be a point in the bottom of the containing vessel. Now, all of the pressure that can possibly be brought to bear on the point O is, by the principle of equal transmission of pressure, bounded by a hemisphere whose radius is equal to the head. But the center of mass of this hemisphere is $\frac{3}{8}$h distant from the base, whence the potential energy would be $mg\frac{3}{8}h$; and equating this with the kinetic energy $\frac{1}{2}mv^2$ we obtain $v = \sqrt{2g\frac{3}{8}h} = .6124 \sqrt{2gh}$ in the plane of the orifice. Bazin's experimental value for this coefficient with orifices 4 to 8 inches in diameter is about .604, while Ellis found for larger diameters about .601. The difference of about $1\frac{1}{2}$ per cent. can be accounted for in the fact that the coefficient above applies solely to a point, which would be the fundamental constant for horizontal orifices with a perfect liquid. We also learn from this that the pressure at the orifice is three-quarters instead of twice the head, confirming the results of Napier and Bazin.

This velocity is that immediately at the orifice. At the instant of passing the orifice an entire release of pressure takes place. The elasticity of the water, supposed perfect, must now restore it to its original volume. The original compression was due to a head h, but three-eighths of this has been used to give velocity at the orifice. The remaining portion, or five-eighths h, must now be restored in expansion, which gives the total head h; and, as $\frac{1}{2}mv^2 = mgh$, we obtain for velocity *beyond* the orifice $v^2 = 2gh$, which, as Bazin states, is entirely gained in the distance r; but while the first expression, $v = \sqrt{2g\frac{3}{8}h}$, applies in the plane of the orifice, the second applies only to the individual particles which have passed through it, the discharge being free into the air and vertical.

As the present object, however, does not concern orifices directly, this part of the subject will not be pursued further.

In speaking of this Torricellian theorem as applicable to river velocities, Major Allan Cunningham, of the Royal Engineers, says

("Roorkee Hydraulic Experiments," Vol. I, p. 145), "For fully a century after Marriotte's time this notion (founded on a supposed but false analogy) proved the most complete hindrance to the science of hydraulics; the double float has certainly done one good service in disproving this notion."

Let us now take up some of the formulæ for the flow of water in pipes, and first the time-honored Chezy formula. (In using the term pipes understand only a closed conduit which is filled at the discharge end, consequently the inlet end must be entirely submerged.) M. Chezy's formula was proposed for open channels, but should be equally, or even more, applicable to pipes.

Adopting the theory of uniform motion, and that in order to obtain such motion the resistance must be equal to the motive force, he assumes, first, that the resistances are directly proportional to the length of the wetted perimeter, multiplied by the length of channel. He also considers them proportional to the square of the mean velocity, since by an increase of velocity a greater number of particles are separated in a proportionally less time, or the total resistances may be expressed by kv^2lp. The motive forces he assumes proportional to the effective component of the weight or to agh, a being the area, g the acceleration of gravity and h the fall in the distance l. Equating these we obtain $kv^2lp = agh$, whence $v = \left(\frac{gha}{klp}\right)^{1/2}$ or calling $\frac{h}{l} = S$, and $\frac{a}{p} = R$, the so-called hydraulic radius

$$v = C(RS)^{1/2}.$$

Instead of analyzing experiments as a whole, analysis to find a value of C suitable for this equation has engaged the attention of very many hydraulicians.

It is proper to remark here that the former method of calling S the sine of the slope is both misleading and faulty. S is the head or fall divided by the length of the pipe; it may be the sine of the slope or may be the tangent. Generally it is neither, but a hybrid. It is an element designed to take into consideration the total frictional or wetted surface of the pipe, R only taking into consideration a section. Later writers designate it as the virtual slope.

Suppose a different assumption be made. The fiction of the hydraulic radius will be preserved, since it has been experimentally shown that in closed pipes the velocities are symmetrically distributed around the center of figure. (I am only aware of four series of experiments on pipes other than circular, and they seem to conform to this law. In comparing circular sections, any linear element, as well as a divided by p, could be taken as the unit of reference.) Assume a plane perpendicular to the direction of flow,

and let us also assume that the mass of water below this plane is offering a resistance to the motion of that above and is being pushed by it. We will then have, if we consider R as the edge of some elementary cube opposed to this pressure, $P \propto R^3$. But, according to the law of free fall, $P \propto h \propto v^2$, hence $v^2 \propto R^3$, or $v \propto R^{\frac{3}{2}}$, and assuming v also to vary with $S^{\frac{1}{2}}$ and making C the general constant,

$$v = CR^{\frac{3}{2}} S^{\frac{1}{2}}.$$

In this shape the formula is used by many river engineers.

TAKE AN ENTIRELY NEW ASSUMPTION.

If we consider the transporting power of the pressure and have P, the pressure required to just move the cube, whose edge is R, we have, as above, $P \propto R^3$. But, as this impulse is proportional to face area and square of velocity (?), we also have $P \propto v^2R^2$, whence $R \propto v^2$ and hence $P \propto v^6$. This may be termed the value of the pressure as connected with its transporting power, or the pressure exerted on the mass of water ahead of any section owing to the velocity of that above it, a condition fully realized in pipes with vertical curves, as inverted siphons.

Now, considering only the ordinary resistances, generally called frictional, of the pipe, the losses due to entrance, bends, etc., having been separated, we find that while in solids the friction varies as the mass, but is independent of the surface, that in liquids it varies as the surface, but is independent of the mass. We have, then, since the surface also varies directly as the velocity, $f \propto v \propto R^2$, and knowing from the law of free fall that $p \propto v^2$, we have $p \propto R^4$, the value of the pressure as overcoming resistance. But since we must have $p = P$, therefore $v^6 \propto R^4$, or $v \propto R^{\frac{2}{3}}$; and again assuming v to vary as $S^{\frac{1}{2}}$, which from the general law of free fall we are justified in doing, we have $v \propto R^{\frac{2}{3}} S^{\frac{1}{2}}$, whence we can write

$$v = CR^{\frac{2}{3}} S^{\frac{1}{2}}.$$

The way the value of the constant C was originally determined is as follows: If in the equation of variation $v \propto R^{\frac{2}{3}} S^{\frac{1}{2}}$, we make the first term definite by the introduction of the mass $\frac{w}{g}$, the second member will also become so by the introduction of a coefficient of resistance $\frac{1}{f}$, whence

$$\frac{w}{g} v = \frac{1}{f} R^{\frac{2}{3}} S^{\frac{1}{2}} \text{ or } v = \frac{g}{wf} R^{\frac{2}{3}} S^{\frac{1}{2}}.$$

This assumption has been opposed on account of lack of homogeneousness in the equation. We will grant this lack, provided it can be shown just what f represents. It is not friction alone; it is not viscosity alone. The element of weight necessarily enters into it, as also the element of time. We are, however, willing to allow the expression to stand as empiric until f is analyzed.

While we could say we hunted for a suitable value of C, the simple way in which we arrived at just the value required on the first trial is worthy of note.

This form has been submitted by Gauckler, by Hagen, by Heinemann, by Foss, by Thrupp, by Vallot, and still later by W. Santo Crimp and C. E. Bruges, but none of whom, to my knowledge, has attempted to justify it theoretically or presented it other than as an empiric formula for special cases.

If we put the average values of w and g in this, or w equals 62.42 pounds, g equals 32.16 feet, we obtain $v = \frac{.513}{f} R^{2/3} S^{1/2}$.

Now, *simply for convenience,* and in order to use about the same value of n as given in Kutter's complicated formula (in justice to the Kutter formula we will state that it was not designed for pipes), multiply this coefficient by 3, and calling $3f = n$ there results

$$v = \frac{1.54}{n} R^{2/3} S^{1/2},$$

a formula which, for ordinary purposes, is equally accurate with and of as wide application as Kutter's, but which, with his, fails in extreme cases. n will not rigidly follow his values, yet in many cases it is even more steady. For values from $n = .008$ to $.018$ it may be taken the same. Getting much above these values, either in Kutter's or this formula, there is no more danger of error in estimating C direct than there is in estimating n, if we get in the habit of thinking C as we have of thinking n. If proof be desired, read the tables of n in Trautwine and Hering's "Kutter," where, while C varies from 125 to 188, n varies from .0218 to .0452, or C varying from 45 to 94, n varies from .0296 to .0425. I have used this formula for nearly six years in the form $v = \left(\frac{1.54}{n} - \frac{2}{R}\right) R^{2/3} S^{1/2}$, as this correction makes it more suitable for small hydraulic radii (more especially in open channels) when n is considered constant for the same class of surface. For large R the correction disappears.

With $n = .013$ Kutter's value for brick sewers, the above would become $v = 118 R^{2/3} S^{1/2}$, while Messrs. Crimp and Bruges give 124 for the constant term.

Incidentally, it should be stated that it is just as applicable to open channels as to pipes, under the ordinary assumption that R equals the area divided by the wetted perimeter.

To make a few comparisons:

Mr. J. C. Quintus measured the discharge of the Niagara River at this place. From his measurements are deduced $R = 22.89$, $S = .000144$, $v = 4.941$. If we make $n = .030$ in the formula, this being Kutter's value for large streams, we obtain the same.

In *Engineering News* for April 4, 1895, is given the following experiment on a 21-inch cast iron main, made in Seville, by Charles A. Friend: $R = .4375$, $S = .0015118$, $v = 2.951$. This would require $n = .0113$ in this formula, Kutter's requiring $n = .011$.

Desmond FitzGerald, in a paper read before the American Society of Civil Engineers (see their Transactions for January, 1896), records a series of very valuable experiments made on a 48-inch cast iron pipe known as the Rosemary pipe. Taking three of these experiments on the pipe after cleaning and applying the value of n as deduced from Mr. F. P. Stearns' previous experiments on the same pipe, or $n = .0108$, which we find from Trautwine and Hering's translation of Kutter is the same value as required by Kutter's formula, we find:

R.	S.	v MEASURED.	v CALCULATED.
1.0	.0000182	.539	.608
	.0005726	3.387	3.412
	.0026110	7.245	7.287

It will be seen that for the very low head this formula, like Kutter's, does not give quite such close agreement as for greater heads.

In the lately talked of Pequannock main of the East Jersey Water Company, 48 inches diameter, of lap-riveted steel, if we take the data given by Mr. Hering in *Engineering News* of January 23, 1896, $R = 1.0$, $S = .002$, $v = 4.45$, we will find $n = .0155$, which we will also find is the average value of n in Kutter's formula as deduced from Herschel's experiments on the Holyoke flume of similar construction. (See Trautwine and Hering's Kutter before referred to.)

BUT ARE ANY OF THE FOREGOING ASSUMPTIONS CORRECT?

If we desire a formula for a special purpose we find Dr. Lampe's formula for iron pipes, which may be written

$$v = 203.3\ R^{0.694}\ S^{0.555},$$

and that of William E. Foss, of the Boston Society of Civil Engineers, and given in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. XIII, for the same case, which may be written

$$v = 191\ R^{0.7272}\ S^{0.5454},$$

and Professor Osborne Reynolds' formula, given in the proceedings of the Royal Society of London for 1883, which may be written

$$v = CR^{3x-1}\ S^{k},$$

all of which decidedly express that v does not vary either with $S^{1/2}$ or with $R^{1/2}$, unless as particular cases. Professor Reynolds' derivation also shows that k is a variable only for the particular condition of the surface of the pipe. The formula was deduced by his system of logarithmic homologues. Varying his process a little, let us now examine actual experiments, and for the present relegate theory to the background.

In Colonel Mark Beaufoy's "Nautical Experiments" (1795) is given the solution of the ordinary exponential formula, which he calls Garnett's Theorem, and applies to the discussion of his experiments on water friction. That is, if we have an equation of the form $v = S^x$, then $x = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } S - \text{Log } S^1}$.

In order to illustrate it, let us take the following four series, comprising twenty-two experiments on wooden pipes, flowing full:

Of these Nos. 1 to 5 were made in California by Hamilton Smith, Jr., on a newly-bored redwood pipe of about 1.25 inches diameter. Quantity discharged, and therefore v, was determined by direct measurement; S was determined by an engineer's level, the head being corrected for loss due to contraction at entrance of pipe.

Nos. 6 to 13 were made in France, by Messrs. Darcy & Bazin, being their Series 52, as reported in their "Recherches Hydrauliques," on a rectangular pipe of unplaned poplar plank 1.575 feet wide and .984 feet deep. Q was determined by weir measurement in these experiments, and S was determined by piezometers. Nos. 14 to 21 are by the same experimenters, on the same kind of pipe, except that it was 2.625 feet wide and 1.64 feet deep. They are reported as Series 51. Q and S were determined in the same manner as the preceding experiments.

No. 22 was made on the Moon Island conduit pipe, in Boston, by Eliot C. Clarke, and is reported in his work on Boston main drainage. It was a square pipe of planed plank, measuring 6 feet on a side. Q in this experiment was determined by pump measurement. The value of S here given may not be exact, as it is calculated inferentially from the data given in his report instead of from direct record. He records the value of C in the Chezy formula, giving R and v. It is therefore simple to find S, though the final figure of decimals may vary to a very limited extent from the truth.

In the fifth column of the table is placed the values of v as calculated by the formula about to be deduced, for comparison with value of v as obtained by actual measurement, the total difference being only about one-half of one per cent.

EXPERIMENTS ON WOODEN PIPES.

No.	R.	S.	v MEASURED.	v CALCULATED.	ERROR %.
1.	.0263	.02419	1.653	1.752	6.
2.		.05094	2.469	2.561	4.
3.		.07610	3.008	3.142	4.6
4.		.10306	3.519	3.668	4.
5.		.13115	3.986	4.148	4.
6.	.3028	.000533	1.230	1.255	1.6
7.		.001067	1.778	1.789	0.5
8.		.001733	2.277	2.291	1.
9.		.002733	2.940	2.890	–2.
10.		.003867	3.530	3.449	–2.3
11.		.006267	4.350	4.412	1.4
12.		.007267	4.626	4.758	2.
13.		.008800	5.308	5.246	–1.
14.	.5046	.000475	1.667	1.658	–0.6
15.		.001076	2.520	2.516	
16.		.001899	3.373	3.362	
17.		.002911	4.226	4.180	–1.
18.		.004272	5.069	5.083	
19.		.005063	5.528	5.543	
20.		.005760	5.915	5.922	
21.		.006614	6.375	6.354	
22.	1.500	.0008428	4.800	4.560	–5.
Totals.			80.147	80.539	0.5

Now let us examine these experiments and see if we can find a formula which will represent the entire series, and which can be expressed in the form $v = CR^xS^y$.

Taking logarithms, $\text{Log } v = \text{Log } C + x \text{ Log } R + y \text{ Log } S$, and for the next state $\text{Log } v^1 = \text{Log } C + x \text{ Log } R + y \text{ Log } S^1$.

But R and C being constant for the same pipe, we find by subtracting the second of the above equations from the first and solving for y, $y = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } S - \text{Log } S^1}$, or Garnett's Theorem, which expression is the equation of a straight line whose co-ordinates are the logarithms of v and S respectively.

Plotting, then, these experiments by logarithmic co-ordinates, the experiments being shown in circles on the accompanying plate, No. 1, we find that parallel straight lines can be drawn through each series of experiments at the constant inclination, indicated by the above formula of $y = .51$.

Now prolong all of these lines until they intersect the axis of v. These intersections show the logarithms of the velocities at the point at which $S = 1$ for each different value of R, and where, consequently, $\text{Log } S = 0$.* Substituting this particular set of velocities for v in the original formula we will in all cases have $S = 1$, and the formula reduces to $v = CR^x$. . . . (a) Again taking logarithms, we obtain in the same manner as before

*There would be a decided flavor of the absurd in this construction if S represented only the sine of slope.

$$x = \frac{\text{Log } v - \text{Log } v^1}{\text{Log } R - \text{Log } R^1};$$

therefore plotting the logarithms of R, as shown in double circles in the plate in connection with these special values of v, we obtain by the corresponding line, which passes very closely through all of the points thus located, $x = .66$. That is, $v = CR^{.66} S^{.51}$. But when R becomes 1, or its logarithm = 0, equation (a) reduces to $v = C$ or $\text{Log } v = \text{Log } C$, or the logarithm of C is found at the point where the line for $R = 1$ and $S = 1$ crosses the axis of v, shown on the plate by the larger set of circles.

Reading this logarithm from the drawing, and finding the corresponding natural number, the complete equation for the case of wooden pipes becomes

$$v = 129\, R^{.66}\, S^{.51}.$$

The results of these experiments as calculated by this formula are given in the table.

Taking these experiments *alone,* the formula $v = 140\ R^{.687}\ S^{.52}$ will give a little closer results. The reason for adopting the form given will be seen presently.

By this method the following experiments have been examined:

CLASS.	SERIES.	EXPERIMENTS.
Wooden pipe.—Smith, Darcy and Bazin, Clarke...	4	22
Tin pipe.—DuBuat, Bossut..................................	4	42
Lead Pipe.—Darcy, Iben, Bossut, Provis, Leslie, Jardine, Couplet, Neville, Hodson................	11	79
Glass pipe.—Darcy, Smith..................	5	32
New wrought iron and asphalt coated pipe.—Darcy, Smith, Couplet, Crozet, Tubbs, Rowland, Iben, Gale, Ehmann, Lampe, FitzGerald................	37	216
Coal-tarred, galvanized and lap-riveted pipe.—Iben, Ehmann, Brush, Herschel..................	11	86
New cast iron and cement-lined pipe.—Darcy, Ehmann, Iben, Russell, Fanning, Friend, Woods, Stearns, Meunier, Bruce..................	17	103
Old cast iron pipes (cleaned).—Darcy..................	4	30
Lightly tuberculated, rusted or with slight mud deposits.—Darcy, Couplet, Iben, Ehmann, Duncan, Simpson, Leslie, Greene, McElroy, Meunier, Humblot, FitzGerald, Bailey, Sherrerd, Forbes, Coffin..................................	32	142
Heavily tuberculated.—Couplet, Iben, Fanning...	9	49
Uncertain classification, but supposed earthenware.—Murray, Bidder..................................	6	8
Rejected.—Darrach	6	53
Brick conduits.—Tracy, Clarke, Elliott, McElroy, Artingstall and unknown author.......... ...	7	38
Total.—12 classes, reported by 44 authors...	153	900

Upwards of one thousand experiments have been examined since, with very gratifying results.

The Darrach series were rejected, as they seem to be interpolations and not experiments; the value of v increasing in an arithmetical progression with that of S, which is a result manifestly impossible and directly opposed to the results obtained from the other 147 series and 847 experiments. Plate 3 also clearly shows the impossibility. (On referring to the original paper they will be found given as "deduced tables." They cannot, therefore, be classed as experiments.) The Murray series are also of little value, having been, in part at least, misquoted by Mr. Murray.

These plottings cover diameters from half an inch to 8 and 12 feet, velocities from 0.1 to 48 feet per second, values of S from .0000095 to 10.7419 and lengths from 20 feet to 20 miles.

DeVolson Wood, in Vol. VII of the Transactions of the American Society of Civil Engineers, says about hydraulic engineers that "there is a peculiar satisfaction to them in discarding all that has been done before and finding fault with all their predecessors, and especially with those who have written on the subject." Disclaiming such intent, it must be said, with reference to one eminent scholar who sweepingly condemns the experiments of Iben, Ehmann, Provis, Leslie and others, that had he examined their experiments in this light he would have found very striking confirmation of the general law, many of them equal, and some superior, to his own. While no series of actual experiments have been found worthless, single experiments have been found difficult to analyze until obtaining a consecutive series of the same class from which the law of the exponents could be deduced.

Proceeding in this manner with the different classes, and as shown on the plates in detail, the following table is found for the values of x and y in the formula $v = CR^x S^y$, in which formula, speaking generally, n is a coefficient of rugosity dependent on the mechanical condition of the pipe, and x is a constant of adhesion depending on the physical constitution of the pipe; for example, x for cast iron remains constant at .66, but n varies according to its roughness.

CLASS.	x.	y.
For wooden pipes and cast iron pipes, either new, old, lightly or heavily tuberculated, or cleaned.	.66	.51
For new wrought iron or asphalt-coated pipes........	.62	.55
For tarred, galvanized or lap-riveted pipes............	.69	.48
For tin, lead and zinc pipes..................................	.59	.58
For glass and brass pipes......................................	.61	.56
Large brick conduits.....	.65	.52

One peculiarity of these exponents immediately appears. In every case their sum is constant and equal in every case to x + y

= 1.17, whence the formula can be written $v = CR^{1.17-m} S^m$. (If desired, this can readily be expressed in the simple form $S = C^1 Q^k$, C^1 being a constant varying with diameter and with m, a form adopted by Foss, Flamant and others.) It will be observed that Professor Reynolds finds the sum of the exponents of v and R constant and equal to 3.

If, then, we make the assumption $m = \frac{1}{2}$, we immediately obtain the formula previously deduced theoretically, or

$$v = CR^{2/3} S^{1/2}.$$

It is therefore claimed that for a single general expression involving the above assumption this formula is of as wide applicability as any yet presented.

Next as to the value of the coefficients C.

For wooden pipes there is a gratifying uniformity in the value C = 129.*

For tin pipes the same uniformity is found for C = 192.

For lead pipes the older experimenters are unanimous on C = 189, while the later ones are just as unanimous on C = 168.

For glass pipe C = 169 holds in all but a single series, which drops to C = 141.

In asphalt-coated pipes the largest number of series tend to C = 170, although some fall as low as C = 140, and FitzGerald's experiments on the cleaned Rosemary pipe rises to C = 199. (Incidentally, the sum of the total experimental values of v on the cleaned Rosemary pipe is 63.631 feet. Calculated by the formula $v = 199\, R^{.62}\, S^{.55}$, they would be 63.643 feet, with a maximum error in any one experiment of about 5 per cent.)

For new wrought iron pipe C varies between 127 to 165, with the higher figure predominating.

For galvanized pipe one series only is available, giving C = 166. This value cannot, therefore, be considered firmly established.

†For lap-riveted pipes, as in Herschel's Holyoke flume, C = 79. (The Holyoke pipe sections were about $4\frac{1}{2}$ feet long. The Pequannock main sections are about 7 feet long. We could infer, therefore, 10 per cent. greater discharge or greater value of C for this, or say C = 87, which would conform to the single experiment given by Mr. Hering. It is, however, stated that the joints were found covered with algae. This might have the effect of throwing it into the lightly tuberculated pipe class, or $v = 105\, R^{.66}\, S^{.51}$. The single

---

*Since this was written several experiments on wood stave pipe have been received, indicating a value for C of about 155 in the same formula. The experiments of Marx, Hoskins and Wing would seem to indicate a value of .58 for the exponent of S, but we would not yet advise its adoption. although the difference may possibly be due to the difference in square and round sections.

†See note at end of paper.

record given is deemed insufficient to properly classify it, owing to the peculiar nature of the obstruction.)

Mr. Morris R. Sherrerd, engineer of the Newark Water Department, has kindly furnished me with data confirming Mr. Hering's figures, and also relative to a 36-inch main of similar construction. While difficult to place these from single experiments, they tend to show that all iron pipe, of whatever nature, tend to the value $v = CR^{.66} S^{.51}$ after a few years of service. The 36-inch main would require $C = 129$ in this form, being four years old.

*Tarred pipes run very evenly, the value of C varying from 115 to 152, with no particular choice. It should be placed at about 120 for general use. The plate submitted, No. 6, also shows that the low coefficient in this formula of $C = 100$ for Iben's "Uhlenhorst" experiments is probably *not* due to some unknown obstruction, as reported, but is entirely due to the nature of the coating.

New cast iron, old cast iron cleaned and cement-lined pipes vary from $C = 126$ to $C = 158$, being very evenly distributed between these values, irrespective of radii. Benzenberg finds 129 for 60-inch pipe.

For iron slightly tuberculated, or with light mud deposits, C ranges from 87 to 132, the majority clustering around 105 as an average value, although the Rosemary pipe shows 117. (Fitz-Gerald's series.)

Heavily tuberculated pipe ranges anywhere from $C = 30$ to $C = 85$. There is nothing to indicate any preference, as in the nature of the case there cannot be.

In large brick conduits C has the value 129 when unobstructed. As many of the experiments in my possession on these were made on conduits obstructed by numerous shafts, they are not fairly comparable with unobstructed pipe. For instance, in the obstructed Fullerton avenue conduit of the Chicago Water Supply $C = 91$; for the obstructed Chicago Land Tunnel $C = 110$, while for the unobstructed Lake Tunnel and the Washington Aqueduct it reaches 129, which is also found by Gaillard's experiments.

The history of an asphalt-coated pipe might be written thus:

New	$v = 175\ R^{.62}\ S^{.55}$
1 year old (or when growing slimy)	$v = 140\ R^{.66}\ S^{.51}$
4 years old (very light tuberculations)	$v = 132\ R^{.66}\ S^{.51}$
6 years old	$v = 124\ R^{.66}\ S^{.51}$
8 years old (light tuberculations)	$v = 116\ R^{.66}\ S^{.51}$
10 years old (average of distribution pipes)	$v = 108\ R^{.66}\ S^{.51}$
14 years old } (varying with amount of tuberculation)	$v = 100\ R^{.66}\ S^{.51}$
18 years old } (varying with amount of tuberculation)	$v = 90\ R^{.66}\ S^{.51}$
25 years old (heavily tuberculated)	$v = 80\ R^{.66}\ S^{.51}$ or less.
	Any of these constants may vary according to the character of the water in hastening or delaying tuberculation.

*See note at end of paper.

In all of these experiments the total head has been reduced by the loss of head, due to contraction at entrance, where not measured by piezometers, by the formula $h' = \frac{v^2}{2go^2}$, o being the coefficient of contraction.

Some of the varying values of C could no doubt be more closely harmonized should we take into account the varying temperature of the water, as did Professor Reynolds, who found that by making a rectangular shift of the lines representing the relative values of v and S through horizontal distances represented by the difference of the logarithms of $\frac{D^3}{P^2}$ for any two pipes, and vertical distances represented by the difference of the logarithms of $\frac{D}{P}$ in which D is the diameter of the pipe and P a coefficient of viscosity depending on the temperature of the water, that better harmony could be obtained. This consideration has been neglected as a refinement unnecessary for the purposes of the present paper.

It is also possible that closer results might have been obtained for some of the cases had a third place of decimals been considered in the values of the exponents.

Every value of C, x and y here given has been obtained directly from the drawings submitted.

The graphical solution of the inverse problem, it will be seen, presents a far less complicated diagram than Kutter's. The process is as follows: Having assumed a value of C, plot its logarithm on the axis of ordinates, and draw an indefinite line on the slope x. If using any particular value of R, at the point where this line crosses the logarithm of R on the axis parallel to that of the abscissæ, draw a horizontal line back to the axis of ordinates, and from this point draw an indefinite line on the slope y. The logarithmic co-ordinates of any point on this line are the logarithms of corresponding values of S and v. That is, three straight lines and a table of logarithms solve the question with all its complications, or these lines may be directly marked with the corresponding natural numbers.

Other simple modifications will readily suggest themselves, as if total friction head for a given length of pipe is wanted, a line drawn parallel to the line last found and at a distance from it equal to the logarithm of the pipe length, measured on the axis of x, will pass through the logarithms of all friction heads corresponding to various velocities. The sewer diagram shows how to include total discharge in cubic feet per second, and how to use all values of n, R, S, v or Q from one plotting.

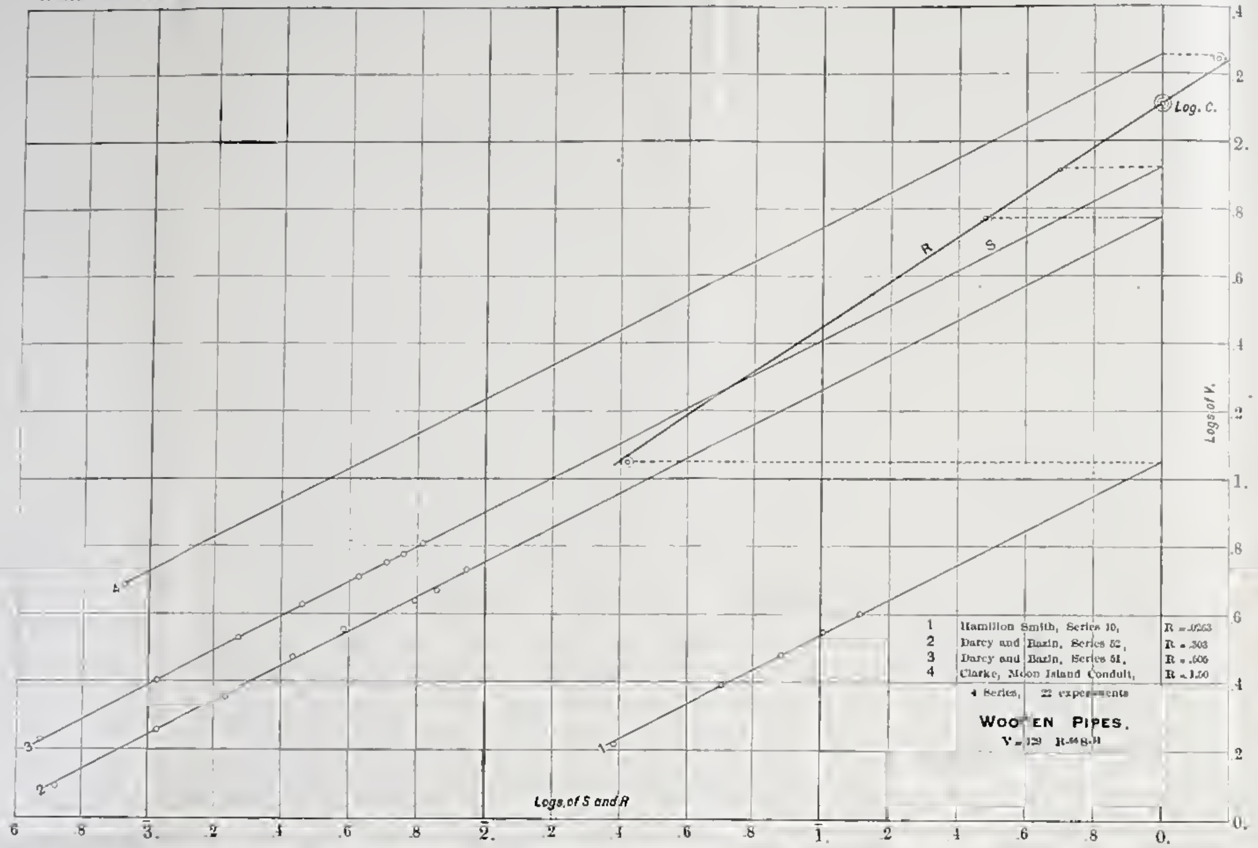
The original intention in this paper was to take up the subject of open channels also, including in this pipes flowing partially full,

FLOW O

96.

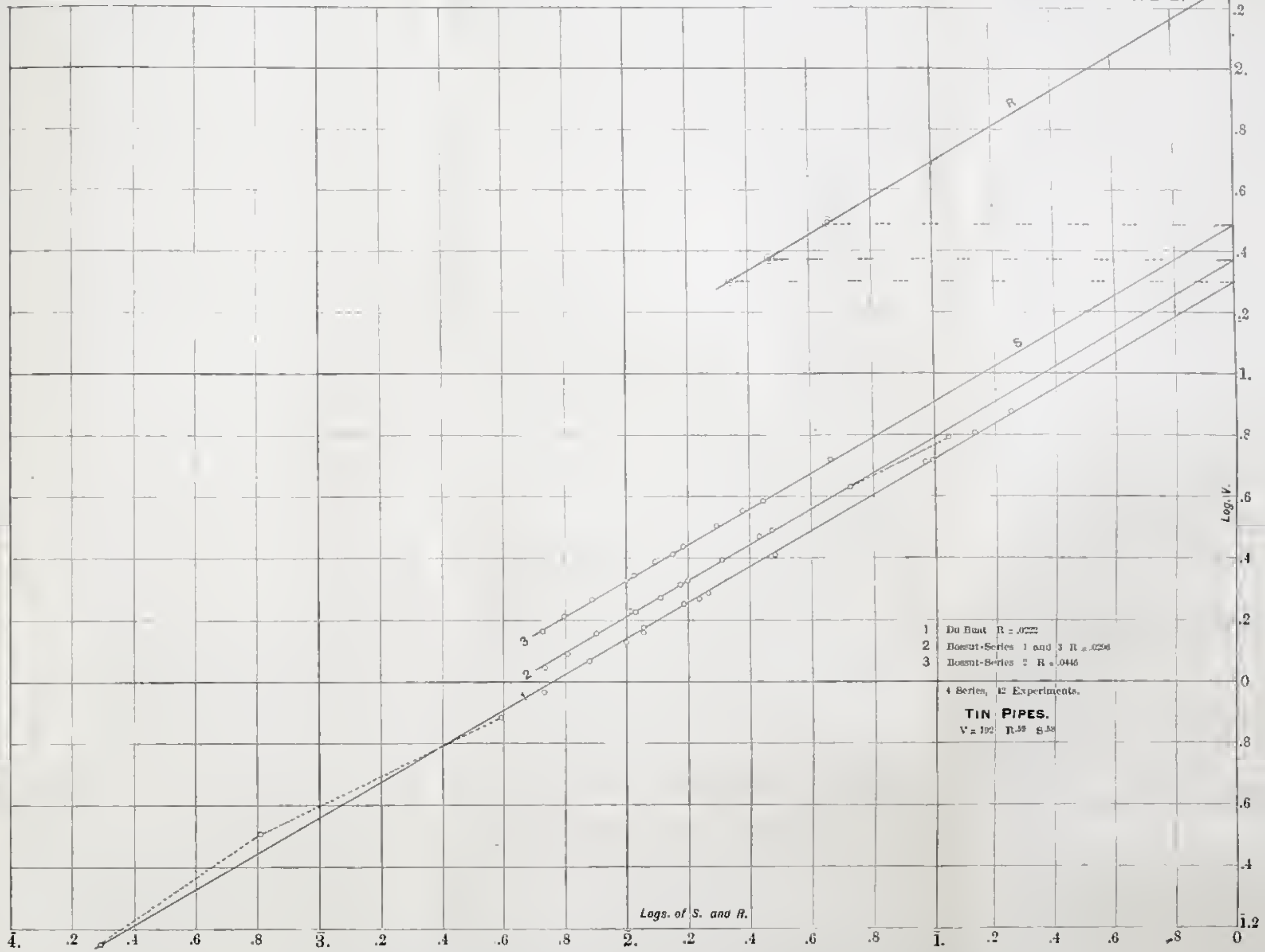
FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899. C. H. TUTTON. PLATE 1.



FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899. C. H. TUTTON. PLATE 2.



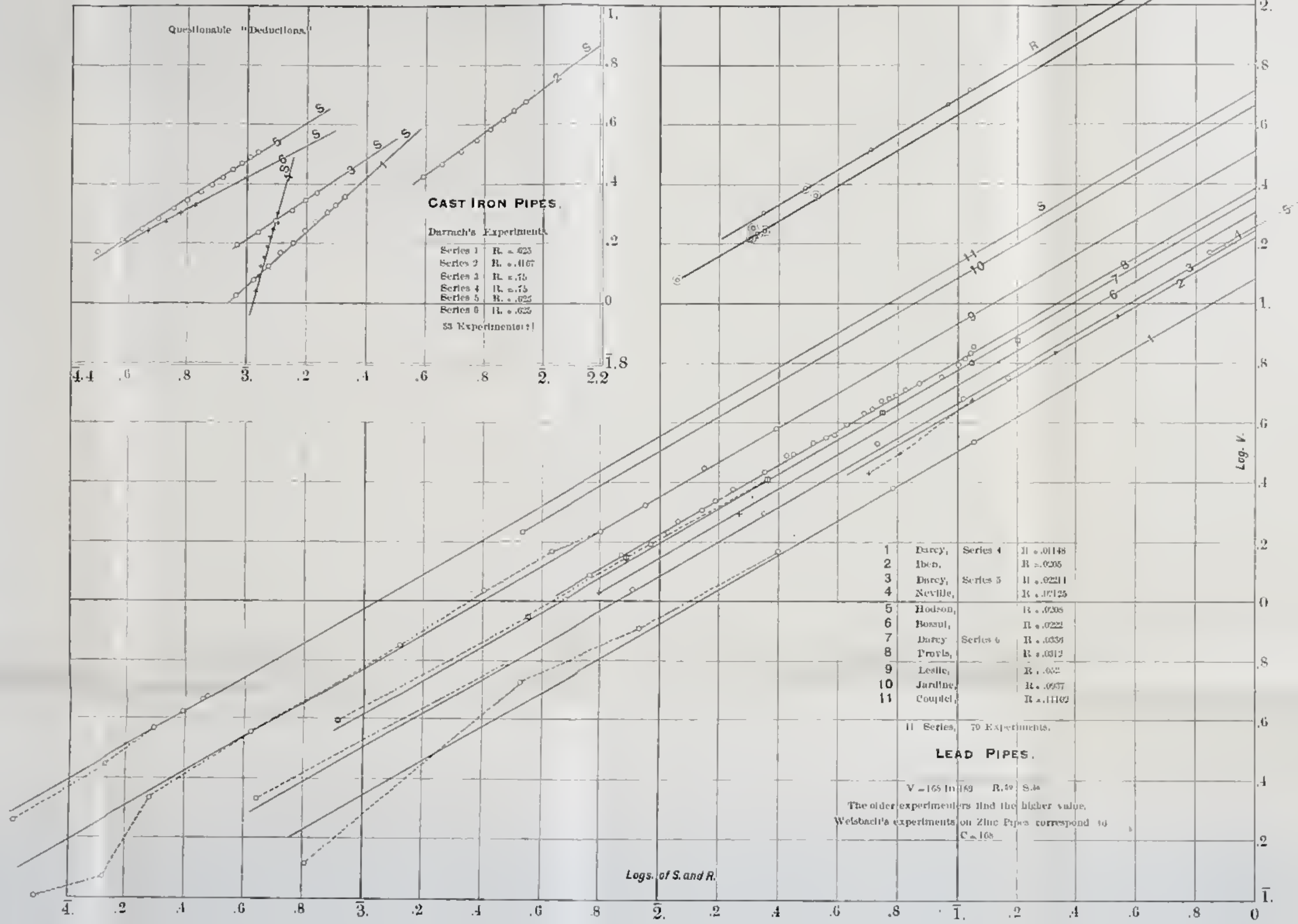
[illegible] [illegible]

[illegible]

[illegible] [illegible]

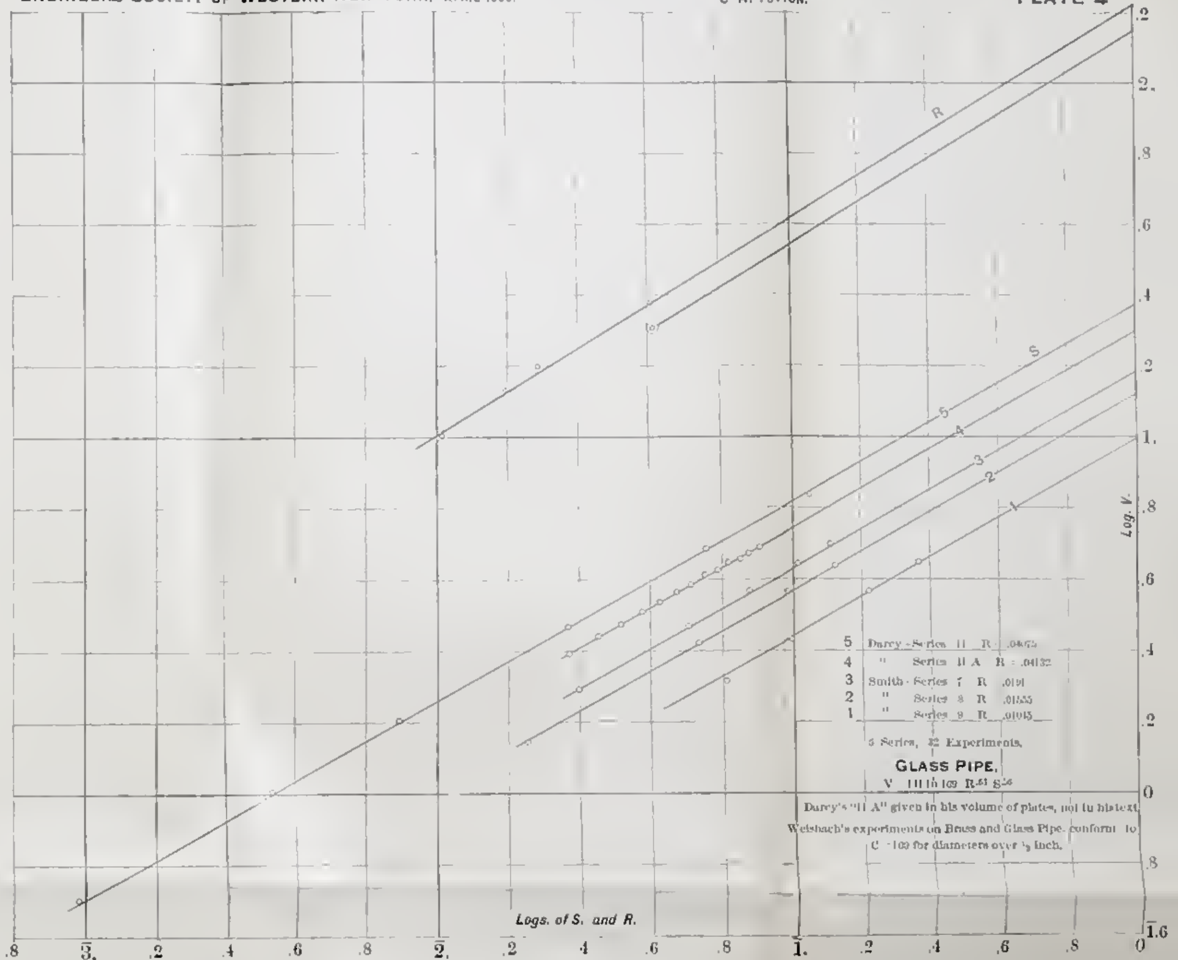
FLOW OF WATER IN PIPES.

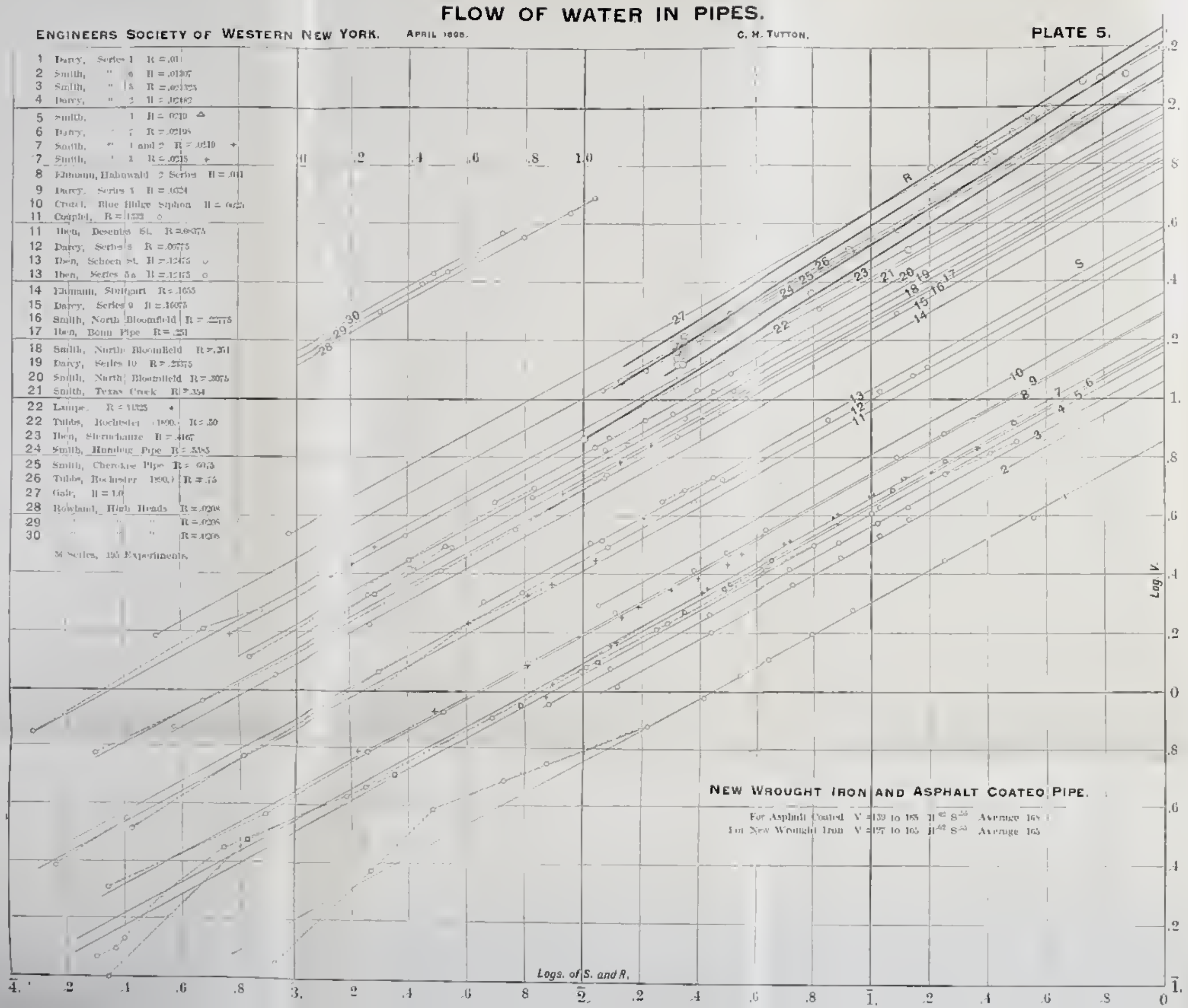
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C. H. TUTTON. PLATE 3.

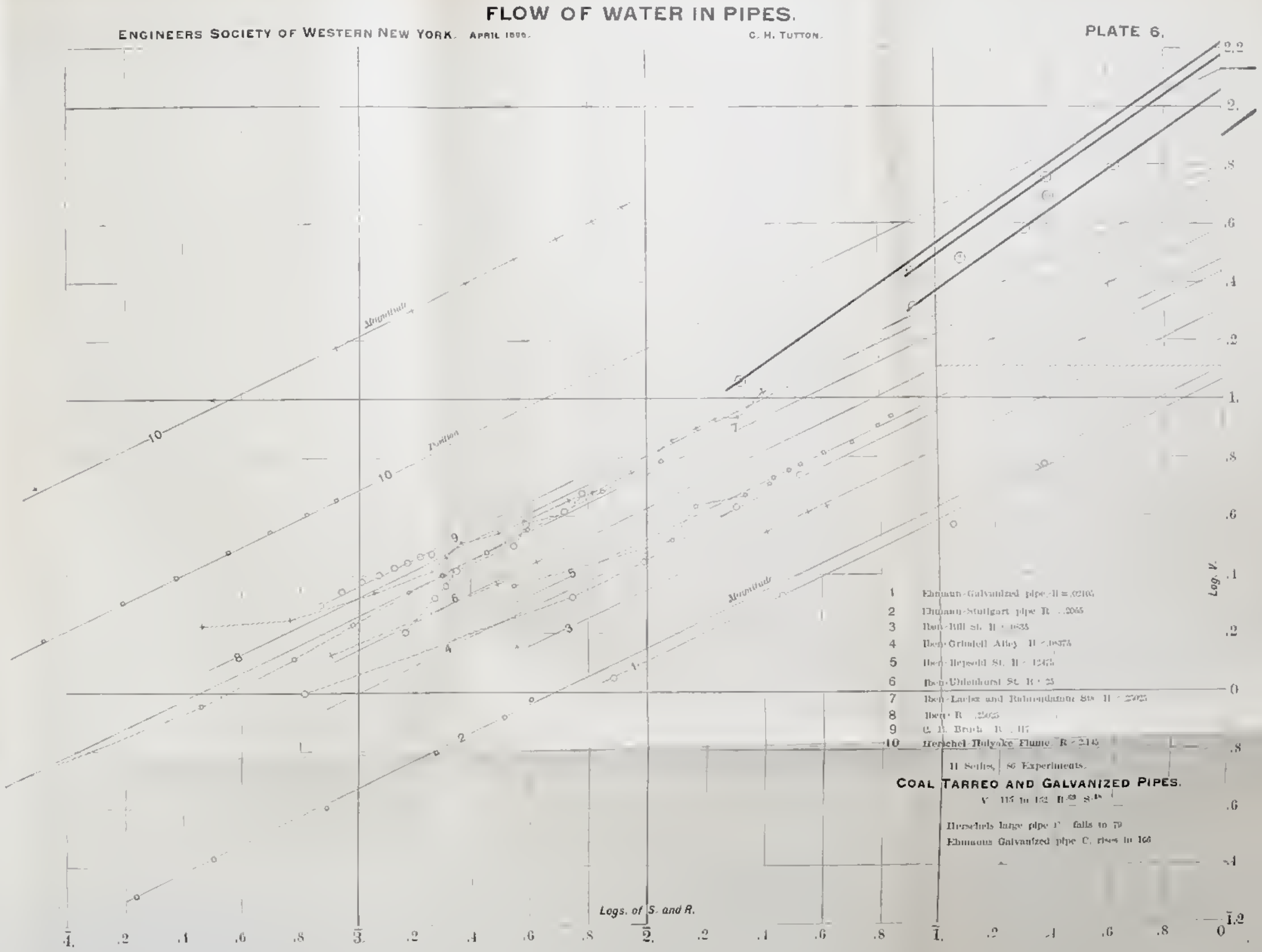


FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C. H. TUTTON. PLATE 4.




FLOW OF WATER IN PIPES.
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899.
C. H. TUTTON.
PLATE 5.
1 Darcy, Series 1 R = .01
2 Smith, " 6 R = .0107
4 Darcy, " 2 R = .0162
6 Darcy, " 7 R = .0198
8 Ehmann, Hahnwald 2 Series R = .041
9 Darcy, Series 3 R = .024
10 Blue Ridge Siphon
11 Iben, Desenlss St.
12 Darcy, Series 8 R = .0775
13 Iben, Schoen St.
13 Iben, Series 5a
14 Ehmann, Stuttgart R = .1655
15 Darcy, Series 9
16 Smith, North Bloomfield
17 Iben, Bonn Pipe R = .251
18 Smith, North Bloomfield R = .251
19 Darcy, Series 10 R = .2375
20 Smith, North Bloomfield R = .3075
21 Smith, Texas Creek
22 Lampe
22 Tubbs, Rochester (1890) R = .50
23 Iben, Sternchanze R = .467
24 Smith, Hunting Pipe
25 Smith, Cherokee Pipe
26 Tubbs, Rochester 1890.) R = .75
27 Gale, R = 1.0
28 Rowland, High Heads
NEW WROUGHT IRON AND ASPHALT COATED PIPE.
Logs. of S. and R.
Log. V.

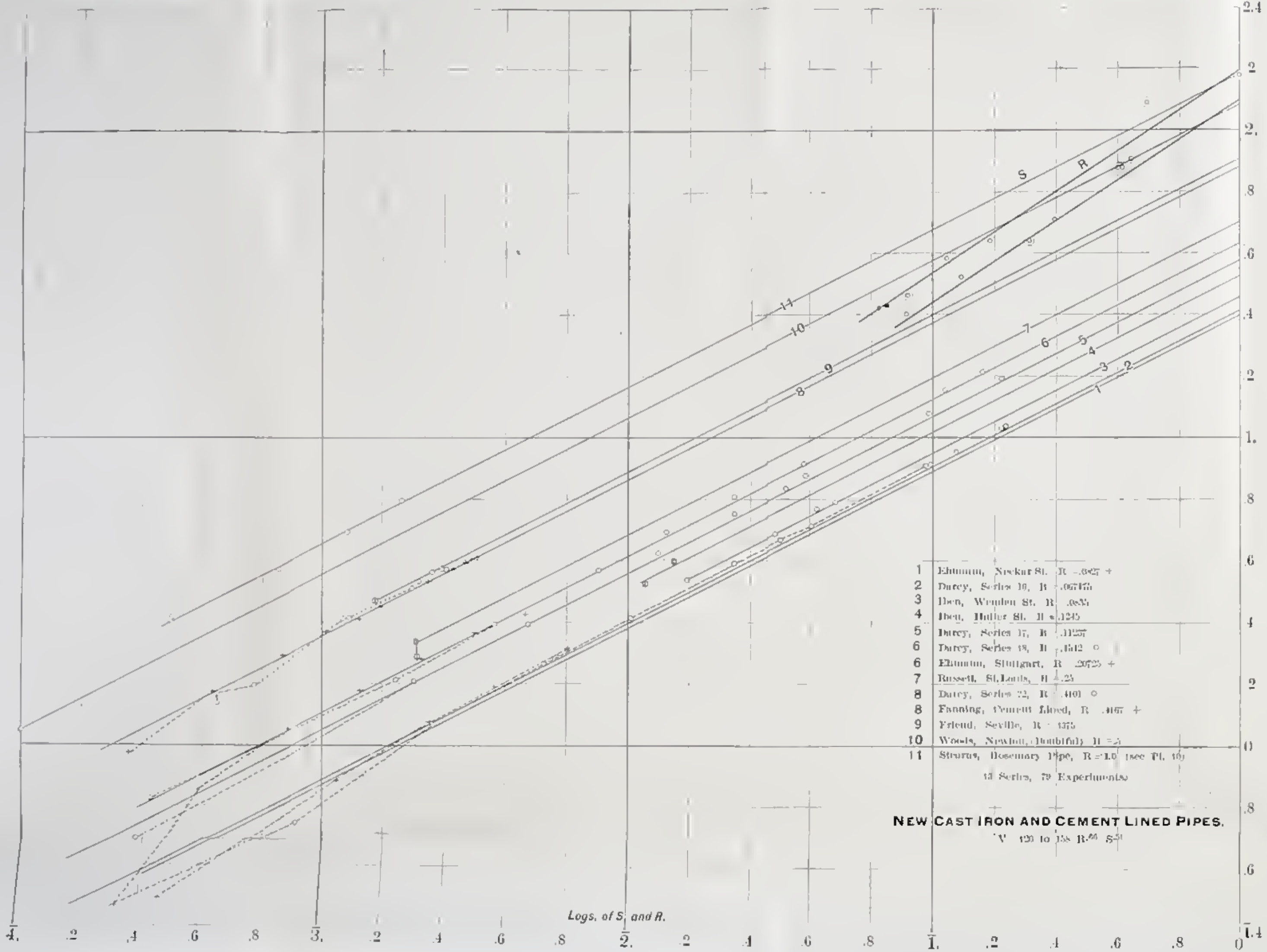

FLOW OF WATER IN PIPES.
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899.
C. H. TUTTON.
PLATE 6.
2 Ehmann-Stuttgart pipe
10 Herschel-Holyoke Flume
11 Series, 86 Experiments.
COAL TARRED AND GALVANIZED PIPES.
Ehmanns Galvanized pipe
Logs. of S. and R.
Log. V.

FLOW

RIL 1896.

FLOW OF WATER IN PIPES.

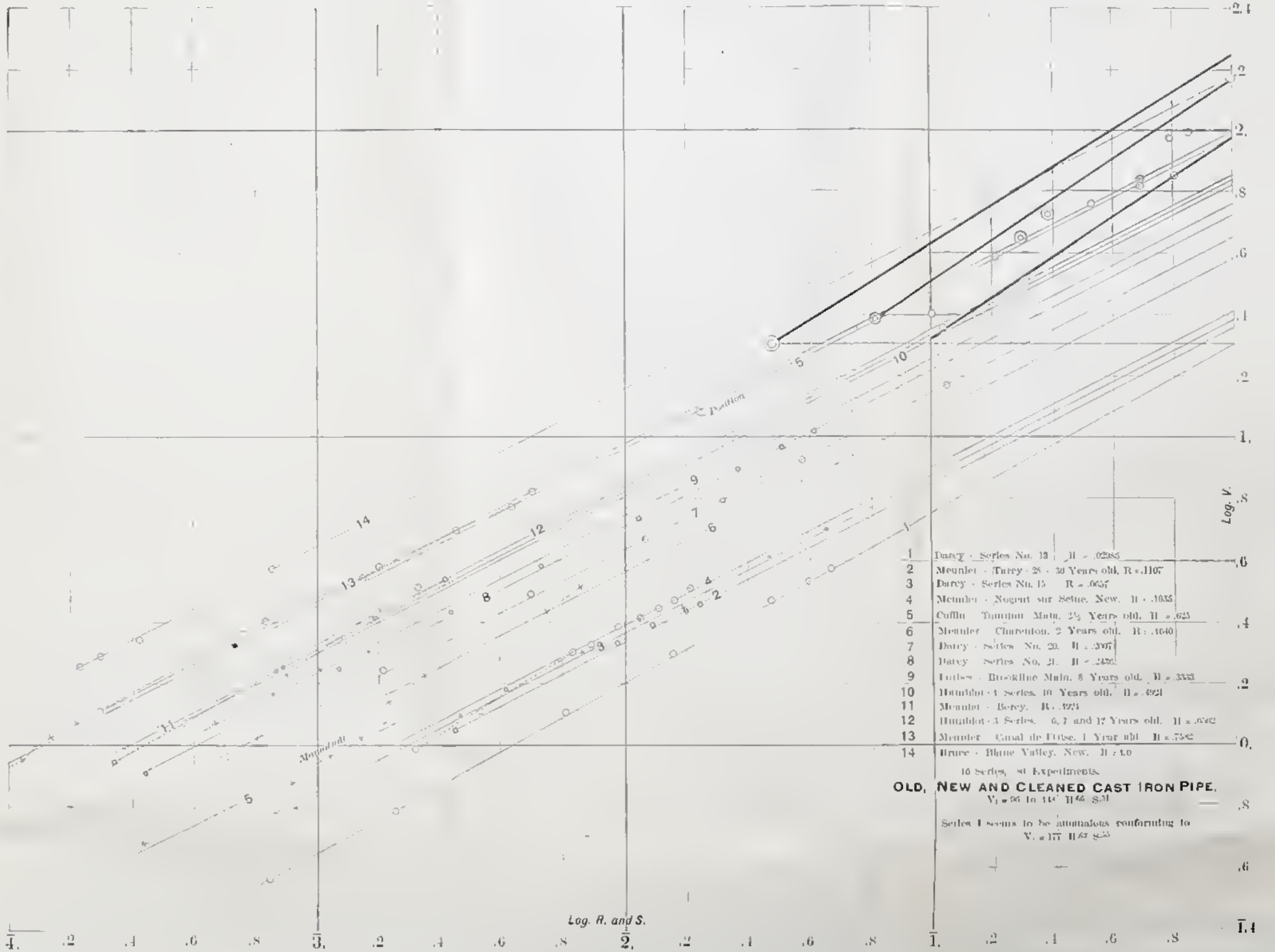
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1896. C. H. TUTTON. PLATE 7.



JOUR. ASS'N ENG. SOCS., VOL. XXIII, No. 4, OCT., 1899. C. H. TUTTON—FLOW OF WATER IN PIPES.

FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1896. C. H. TUTTON. PLATE 8.



8

S

C. H

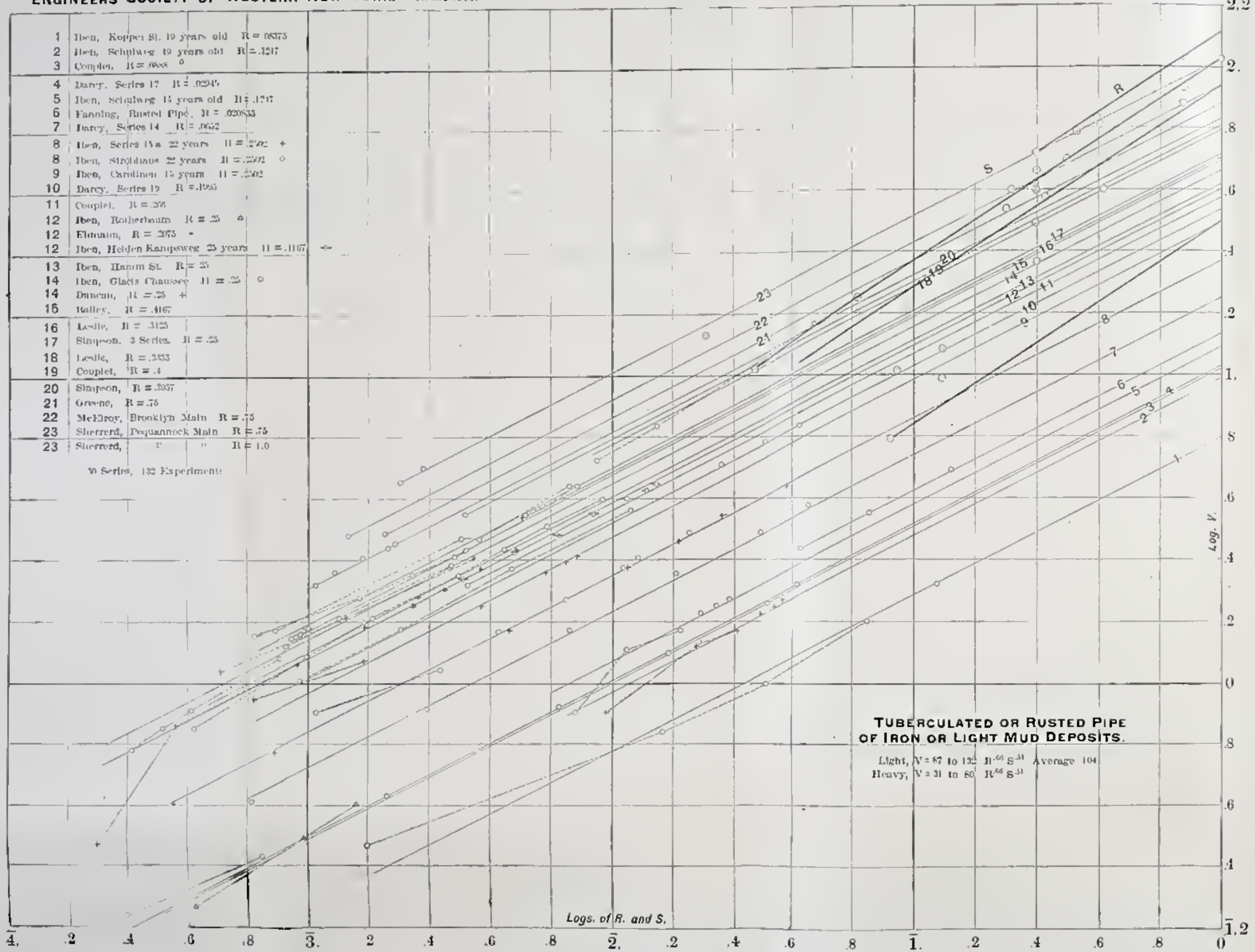
2

2

2

FLOW OF WATER IN PIPES.

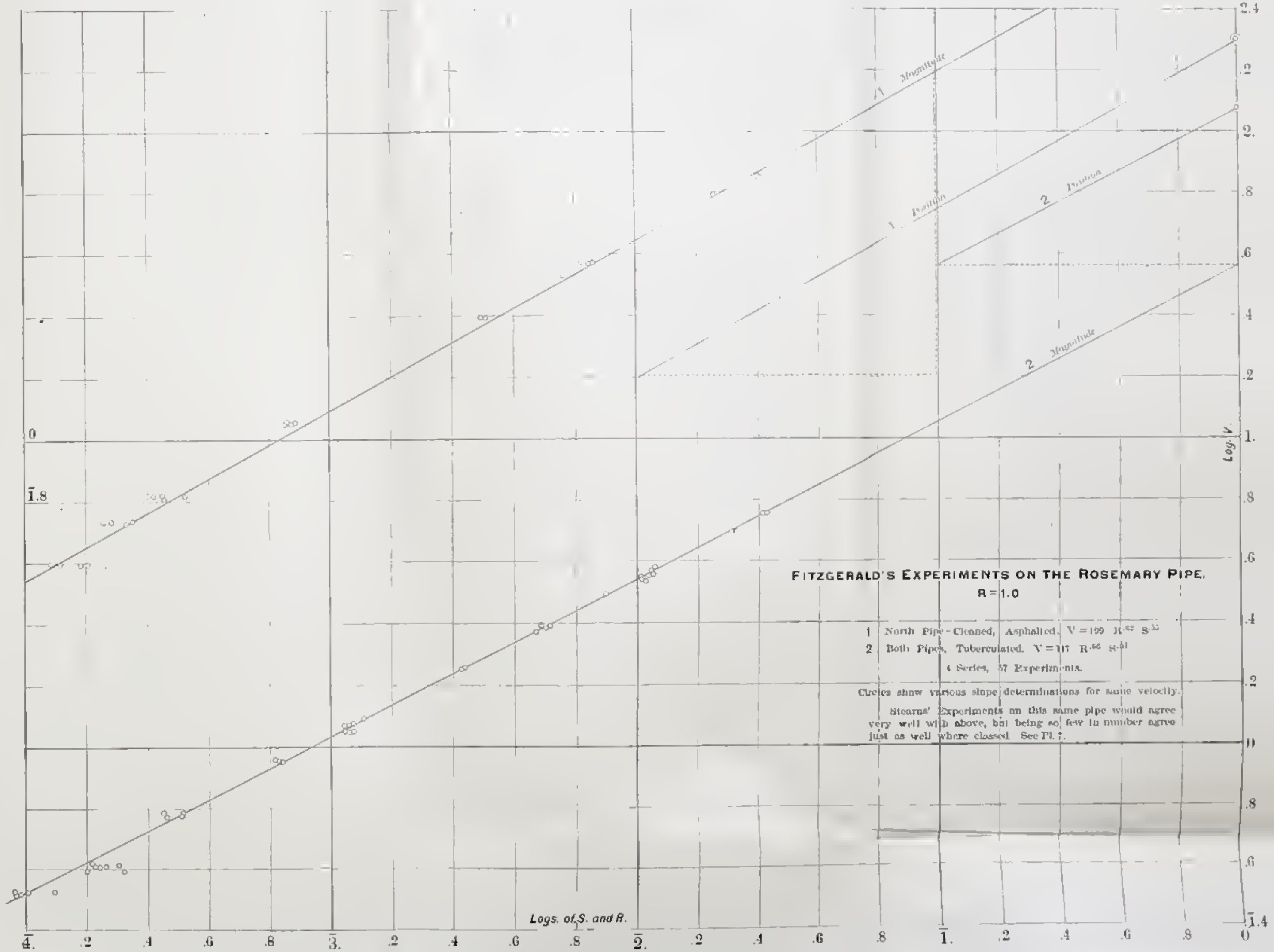
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C. H. TUTTON. PLATE 9.



JOUR. ASS'N ENG. SOCS., VOL. XXIII, No. 4, OCT., 1899. C. H. TUTTON—FLOW OF WATER IN PIPES.

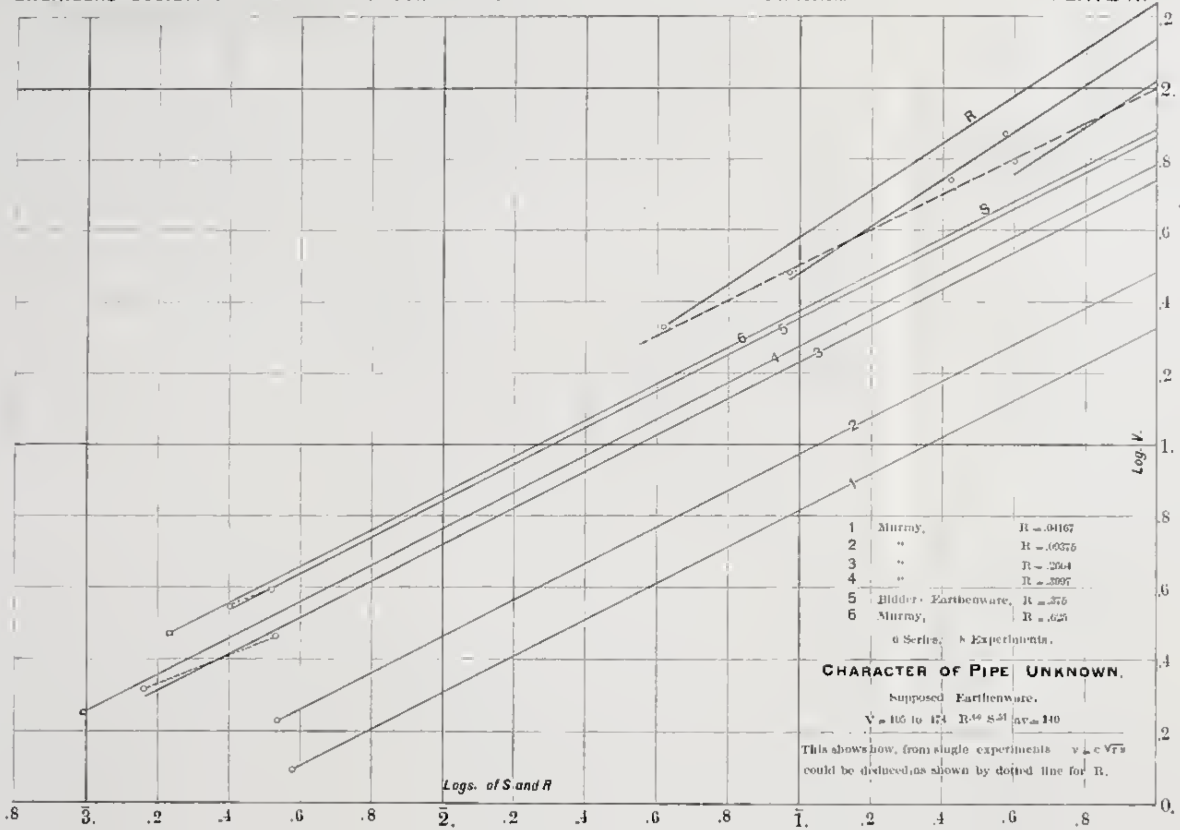
FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C. H. TUTTON. PLATE 10.



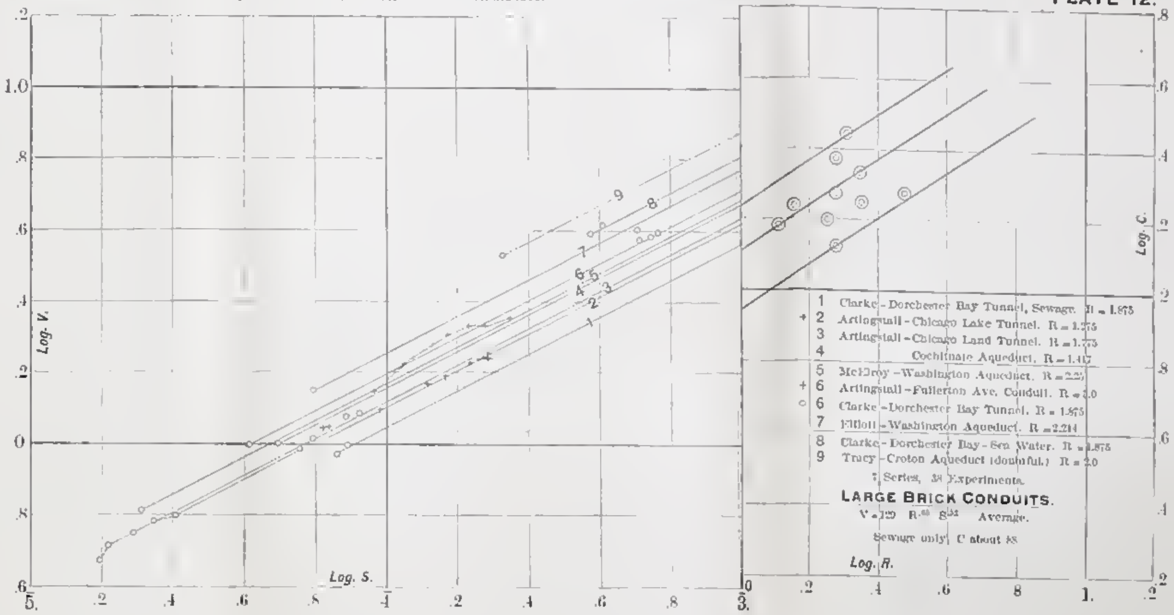
FLOW OF WATER IN PIPES.

ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1898. C H TUTTON. PLATE 11.



FLOW OF WATER IN PIPES.

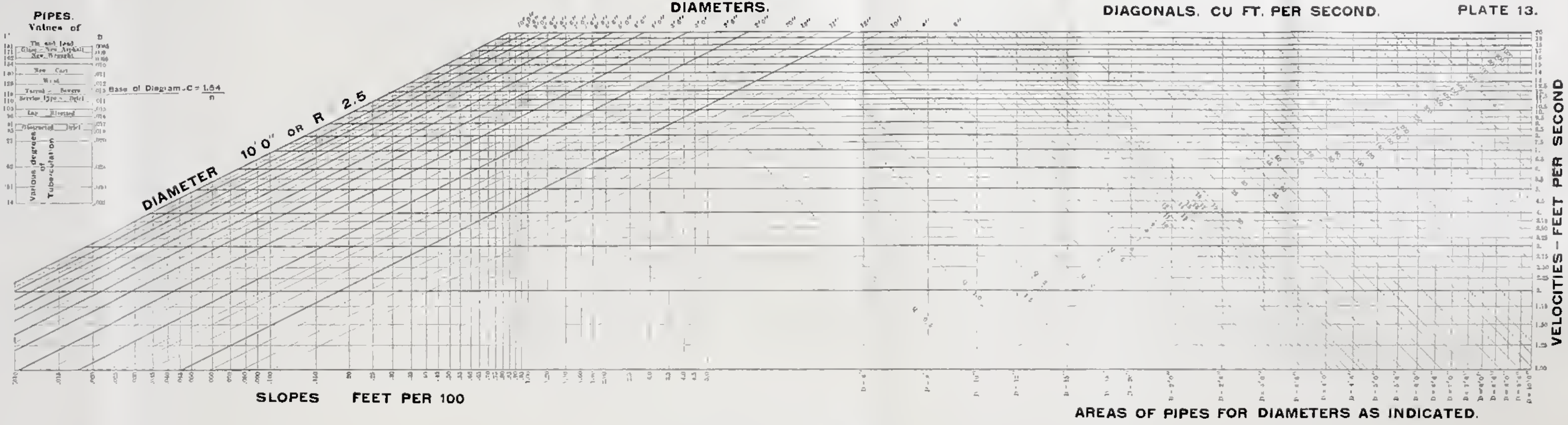
ENGINEERS SOCIETY OF WESTERN NEW YORK. APRIL 1899. C. H. TUTTON. PLATE 12.



SEWER DIAGRAM.

$V. = 118 \, R^{2/3} S^{1/2}$

PLATE 13.



FLOW OF WATER.

This diagram is based on n = .013, the value for sewers.

Example:— A 3 ft. sewer laid on a grade of .25 per 100, has a velocity of 5.0 per second, and carries 35 cubic feet of water when running full.

To dispose of 300 cubic feet of water per second with a 6'-6" sewer, it must have a velocity of 9 feet per second, which requires a grade of 0.30 per 100 feet, or an 8 foot sewer on a grade of 0.10 per 100 and velocity of 6.0 will do it.

To change value of n and use same diagram.

From table "values of n," take in a pair of spacers or on a slip of paper the distance from line "Base of Diagram" to value of n desired. Lay this distance off up or down on the slope lines, (verticals), from the intersection of the line of Diameter (inclined), and use the velocity thus indicated (horizontals) as the proper velocity. Tracing this velocity through to the vertical "D" on right of diagram, it intersects this vertical on the inclined line Q, showing quantity discharged.

A vertical drawn from the foot of any "Q" line corresponds to an *area* in square feet equal to the number of *cubic* feet represented by the "Q" line, and this vertical will intersect any velocity line on a new "Q" line corresponding to the quantity of discharge for that area and velocity, hence by marking R instead of D on the inclined lines on left of diagram, this will include all cases of open Channels within its limits.

The diagram covers—Diameters from 6" to 10 feet or R from .125 to 2.5, velocities from 1 to 20 feet, slopes from .0001 to .05, discharges from 0.5 to 1000 cubic feet.

C. H. Tutton, 1896.

as sewers and water conduits, but, as it has already reached a sufficient length, that will be reserved for a future communication. It may, however be briefly stated regarding open channels that the formula $v = \frac{1.54}{n} R^{2/3} S^{1/2}$ will apply as long as we can consider the flow uniform and surface parallel to bottom inclination, but it will not correctly apply to rapidly rising or falling rivers or to those discharging against tidal action, on which conditions Kutter's formula is, unfortunately, principally based.

NOTE.—The experiments of Rowland on high heads were taken from Trautwine's "Kutter," but there is reason to believe them incorrect, owing to an error in reduction in the original paper in Vol. XIX, Trans. A. S. C. E. The error, however, does not affect their classification.

It is stated in the text that for tarred and lap-riveted pipes $x = .69$, $y = .48$. We have allowed this to remain as in the original to avoid new plates, but would state that a much larger field of investigations indicates $x = .66$, $y = .51$.

For tarred pipe C should have about the same value as for cast iron pipe of the same age, while for lap-riveted pipe it decreases from about 125 or 135 for new pipe to 110 or 114 for pipe "in service." The author regrets that his occupation at present is such as to prevent his giving a more complete paper, including many later experiments, which are not even referred to in the preceding, as in the following list of experiments examined since the original paper was written:

Wood pipe.—Adams, Hardesty, Henny, Marx, Wing and Hoskins.

Lead pipe.—Reynolds, Rennie, Duncan, Robison, Belidor.

Zinc pipe.—Weisbach.

Brass pipe.—Weisbach, Mair.

Rubber hose.—Fanning, Ellis, Francis, Freeman.

Earthenware.—Kuichling, Bidder.

Wrought iron.—Ketchum, Thrupp.

Cast iron, coated.—Weston.

Cast iron, tarred.—Benzenberg, Pearsons, Vodicka, Kuichling.

Old cast iron.—Robison, Chapman, Rafter, Duane, Brackett.

Lap-riveted.—Schussler, Hardesty, Herschel, Rafter, Hawks, Adams, I. W. Smith, Kuichling, Tournadre, FitzGerald, Marx, Hoskins and Wing.

Brick conduits.—Benzenberg, Gaillard, Pasini, Gioppi, Croton.

Linen and leather hose.—Freeman.

Cement-lined.—Bazin, Dumont.

THE DESIGN AND CONSTRUCTION OF A MODERN CENTRAL LIGHTING STATION.*

By H. H. Humphrey, Member Engineers' Club of St. Louis.

[Read before the Club, October 18, 1899.†]

The Keyes ordinance (No. 18,680), passed by the Municipal Assembly of the city of St. Louis, Mo., in the fall of 1896, threw open the doors to all applicants for underground conduit rights. Fourteen companies appeared at the first hearing before the Board of Public Improvements and made formal application for space for electric wires beneath the surface of the streets.

Among the applicants were several newly-organized companies, and one of them has since constructed its plant. The Imperial Electric Light, Heat and Power Company first turned current into its underground system one year ago, October 15, 1898, and has been in continuous and successful operation since that date. This paper is a discussion of the design and construction of this plant, which embodies many interesting features.

After engaging engineers, the first question that confronted the company was the selection of the system of distribution.

This plant was intended primarily to compete for business in the down-town or underground district of St. Louis, which is bounded by Spruce street on the south, Wash street on the north, the Mississippi River on the east and Twenty-second street on the west. It was required, however, that the system adopted should be capable of being extended beyond this district, and, if necessary, of covering almost the entire city. The success of the three-wire direct-current low-tension underground system in this and other countries naturally influenced the engineers in its favor. On the other hand, the cost of copper for such a system, while not strictly prohibitive, is still so large as to demand most serious study.

The class of service to be supplied had great weight in the final decision regarding the system. This service consists largely of 500-volt direct-current motors, there being also some 220-volt motors of smaller size. Another important part of the service was to be arc lighting. The growing popularity of the inclosed arc lamp indicated that this field would be very profitable. The fur-

*The engravings for the photographic illustrations of this paper have been prepared without expense to the Association.—Secretary, Ass'n of Eng. Socs.

†Manuscript received October 25, 1899.—Secretary, Ass'n of Eng. Socs.

nishing of incandescent light was by no means of secondary importance.

In order to reduce the first cost of station equipment and underground work, both conduits and cables, it was deemed advisable that all three kinds of service should, if possible, be supplied from one generator, delivering its output through one underground duct and one service cable.

These considerations led to the adoption of a three-wire direct-current system of distribution, differing in important details, however, from the methods heretofore employed. 220-volt incandescent and 220-volt arc lamps were both to be used on the sides of the three-wire system, while 500-volt motors would be connected directly across the outside wires. The saving in copper over the usual 110-220-volt system, based upon the same percentage of drop, is three-fourths. Furthermore, the area which can be supplied from one central station at the same percentage of loss is increased sixteen times. If in the 110-220-volt system the limit with a certain drop be placed at one mile from the station in all directions, an area of 3.14 square miles can be covered. With the 220-440-volt system the distance reached from the station in all directions is four miles, covering an area of 50.24 square miles. By the proper use of boosters with storage batteries at the ends of feeders, such a system may be extended over a district within a radius of 10 miles from power plant.

The next question in point of importance was the location of the plant. It would be natural to assume that such a plant should preferably be located upon the river front in order to secure cheap water, and upon a railway switch to secure cheap fuel. In this case, however, no suitable property was available on the water front. Furthermore, fuel coming from the Southern Illinois district can be delivered by wagon from East St. Louis almost as cheaply as when bridge and switching charges are paid on carload lots unloaded at the plant. Very few St. Louis power plants are located upon railway switches, and one large plant which is so located is supplied with coal hauled in wagons from East St. Louis. Under these circumstances the plant should be placed as near the electrical center as possible. A suitable lot was found at the southeast corner of Tenth and St. Charles streets, and the plant was located there.

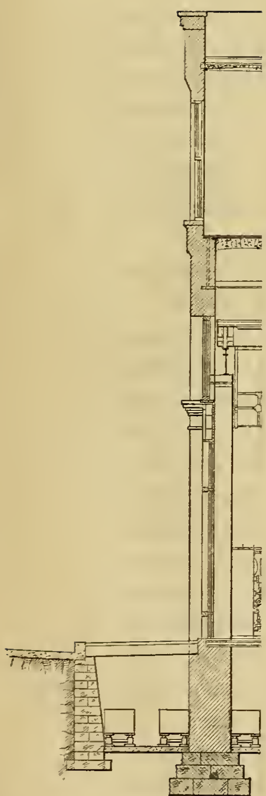
The designing of a plant which would ultimately utilize to the best advantage all the limited space available was next undertaken. Before entering upon the details of this work, however, one of the engineers spent some time on an extended trip through the East,

visiting the large power plants in New York city, Boston, Pittsburg, Philadelphia, Buffalo and Chicago, making a study of the most modern plants in these cities. After much study it was decided to locate the boilers, dynamos and engines all upon the street level, rather than place part of the apparatus below street level, as is frequently done. A study of many different designs led to the division of the plant longitudinally, east and west, into an engine room and a boiler room, each extending the full length of the property; this plan giving an ultimate capacity of 10,000 horse power.

Hypothetical load curves were next prepared, covering the service expected from this plant, including incandescent and arc lights

Fig. 1. Exterior View of Station.

and motor service. The three were then combined into one curve representing the entire anticipated output of the plant under the heaviest service of the winter months. (See Fig. 13.) A study of this curve indicated that the number of units in the plant should be at least five. This number fitted both the minimum load, which was about one-fifth of the maximum, and provided admirably for reserve. In case of accident during the peak of the load, the other four units could take the place of the disabled one by each carrying 25 per cent. above its rating. In case of the adoption of a storage battery



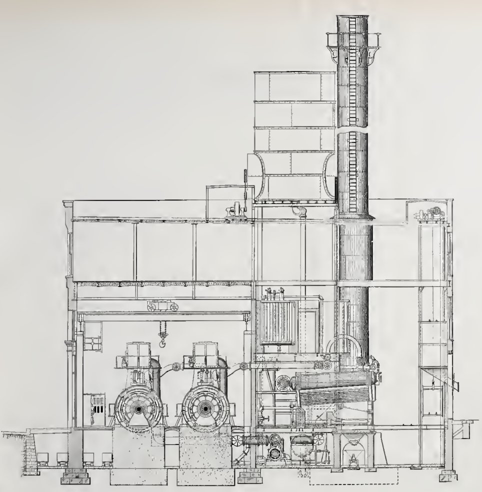


Fig. 2. Cross Section of Plant.

sufficiently large to carry the reduced load during the latter part of the night, and assist the generators during the times of maximum load, it was deemed safe to reduce the number of units to three, the battery to be of the same capacity as each of the units.

In designing steam plant it was necessary to determine beforehand what economical auxiliary apparatus, if any, should be installed in connection therewith, as all of these affect the capacity of the boiler plant. The rule adopted by the engineers in determining whether any species of economical apparatus was worth installing was that it should be able to earn, under a conservative estimate of the conditions of service, and taking into consideration the low price of fuel in this territory, 18 per cent. annually upon its first cost.

Applying this rule to the consideration of compound versus simple engines resulted in favor of the compound engine. A further comparison between compound non-condensing and compound condensing engines showed the ultimate economy to be in favor of the condensing type. Economy in the use of water, which is obtained from the city's mains at considerable expense, necessitated the installation of a cooling tower in connection with the condensing plant.

The application of the above rule to the question of fuel economizers showed that they would be a good investment.

It was decided to use water tube boilers, as this type gives large capacity in small space, is absolutely safe, quick steaming, economical in fuel and can be had in large units. With good draft they may be overworked 50 per cent., and under mechanical draft they may be operated for short periods at double their rating. Down draft furnaces, of the type which has proven so successful in St. Louis, were selected. They are capable of burning low grade coal, running high in moisture and clinker, and may be overworked far beyond the rating of the boilers. They are also simple, easily repaired and not likely to get out of order. The most important characteristic, however, is that they are smokeless, thus complying with the city ordinances. They improve the fuel economy, and add somewhat to the boiler's capacity.

It was decided at the outset to divide the total chimney capacity into two units, for the reason that the draft would be better at light loads, and one stack only needed to be built then, as but a part of the plant was to be installed to start with.

On account of the use of the 220-440-volt system of distribution and the many economical features of the steam plant, this station has attracted unusual attention. A detailed description of

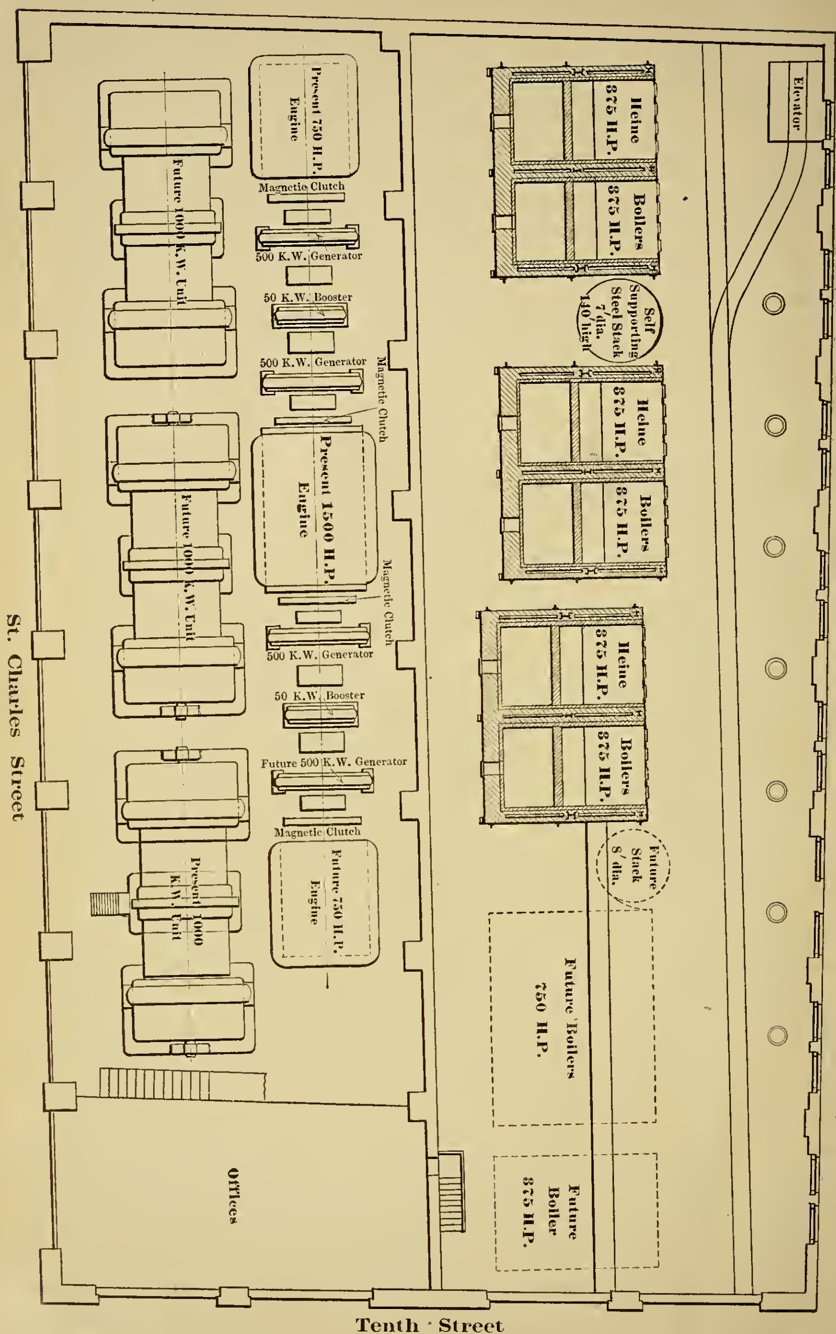


FIG. 3. FLOOR PLAN OF BOILER AND ENGINE ROOM.

the apparatus used therein may therefore have more than passing interest.

BUILDING.

The plant is located at the southeast corner of Tenth and St. Charles streets, on a lot having a frontage of 142 feet 6 inches on St. Charles street by 85 feet $2\frac{1}{2}$ inches on Tenth street and 92 feet $3\frac{1}{8}$ inches on the east line. An exterior view of the building is shown in Fig. 1. Fig. 2 gives a sectional view of building, and Fig. 3 a plan of the engine and dynamo room.

The building is of dark red brick, three stories high above the basement and of same dimensions as the lot above street level. The area under sidewalks on both Tenth and St. Charles streets is excavated to the curb line, which forms the outer line of retaining wall. The second story is omitted everywhere except over the main office, thus giving a clear height in the engine and boiler rooms of 30 feet. The third story, which is 15 feet high, is devoted to store rooms, testing department, etc. The floor of the third story over the engine room is carried on steel girders, resting upon the division wall and on brick piers on the St. Charles street side of the building. The floor over boiler room is supported on I beams resting on steel columns in front of the boilers, and upon the division wall and the outside wall of building on the alley side. The entire structure is fireproof. All floors are of cinder concrete carried on corrugated iron arches sprung between I beams. The roof of book tile with composition gravel covering. Engine and boiler rooms extend the entire length of the building, and are separated by a division wall having fire doors at all openings. Beneath the engine room are the storage batteries, extending partly under the sidewalk. Beneath the boiler room is space for coal storage, ash handling and the location of condensing apparatus and piping. The floor of engine room is laid with hexagonal tile, and the walls for 6 feet above the floor are wainscoted with marble. The main offices of the company occupy the Tenth and St. Charles street corner on the first floor. The private offices are in the second story, directly above. An elevator at east end of the boiler room runs from basement to third floor.

BOILERS.

There are four Heine boilers, Fig. 4, arranged in batteries of two each, with one stack between them, and economizers in the rear of and above the boilers. Each boiler contains 171 $3\frac{1}{2}$-inch water tubes 16 feet long. The total square feet of heating surface of the four boilers is 10,872. Each boiler has a rated capacity of

11,250 pounds of water per hour with feed water from the economizers at 200° F., into dry steam of 175 pounds pressure above atmosphere, and is guaranteed to be capable of developing continuously one-third more. Efficiency guarantee is 70 per cent. of the calorific value of the coal at any load between rating and 20 per cent. above. This is equivalent to evaporating 7.21 pounds of water per pound of Mount Olive nut coal of 10,600 B. T. U. The boilers are designed for a working pressure of 175 pounds per square inch, and tested under a hydrostatic pressure of 250 pounds. The

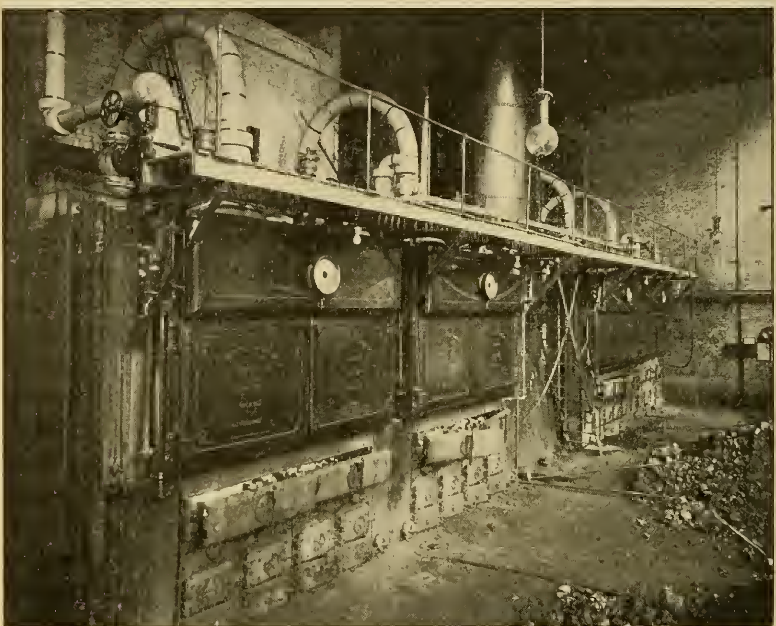


Fig. 4. Front View of Boilers.

entrainment is guaranteed to be less than 1 per cent at rating, and not more than 1½ per cent. at one-third above rating. Each boiler is equipped with the down draft furnace. A feature of these furnaces which is original with the engineers is making the fire doors open the full width of the furnace, greatly facilitating inspection and care of the fires. Two additional Heine boilers of the same capacity are now being installed.

CHIMNEY.

The present boilers are served by one steel stack, Fig. 5, 7 feet inside diameter, 140 feet high above street level. The design of the complete plant provides for another 7-foot or 8-foot stack for

the additional boilers, which are to go in. The lower 10 feet of the present stack are made of $\frac{1}{2}$-inch steel plates; the next 20 feet of $\frac{3}{8}$-inch plates; the next 25 feet of $\frac{5}{16}$-inch plates, and the next 85 feet of $\frac{1}{4}$-inch plates. It is self-supporting and unlined. There is a ladder extending up from the roof of the building, and an ornamental platform surrounding the top. The base is supported upon and rigidly bolted to a massive brick foundation 14 feet deep, and which is solid except for the ash car passage which extends through it. The stack is provided at the base with suitable door for cleaning. Through the third story of the building it is surrounded by a sheet steel casing which provides ventilation for the boiler room. There is an improved draft gauge by which the draft can be read to thousandths of an inch at eight different points, including ash pits of four boilers, two breechings, inlet to draft fan and base of stack.

MECHANICAL DRAFT.

In order to counteract the effect of the economizers in cooling the gases from the boilers, and to permit crowding when necessary, a mechanical draft system was installed. It is of the induced type, the fan being placed directly behind the stack and between the two batteries of boilers. The bearings of the fan are self-lubricating and water cooled. This fan is driven by means of a direct-geared electric motor, designed to be operated at different speeds on either the 235- or 470-volt circuit. This motor is to be controlled automatically, so as to maintain the steam pressure practically constant, the regulator slowing down the motor as the steam pressure rises and increasing its speed as the pressure falls. The capacity of the fan is sufficient to handle the waste gases from four boilers and furnish a draft equal to 1 inch of water where the gases leave the boilers. It is capable of being speeded in emergencies sufficiently to give a draft of $1\frac{1}{2}$ inches on all four boilers.

FUEL ECONOMIZERS.

There are two Green fuel economizers, each consisting of 320 pipes, the combined heating surface being 7680 square feet. The economizer plant is capable of heating regularly and continuously 45,000 pounds of water per hour 100° F. when receiving the water at 110° F., and with the temperature of the escaping gases leaving the boilers at not less than 450° F. One-third more water may be passed through in case of necessity, but of course with diminished economy. These economizers are designed for a working pressure of 200 pounds per square inch, and were submitted to a hydrostatic test of 300 pounds after erection in position. They are provided

with automatic scrapers operated by electric motors. The economizer plant is provided with pop safety valves, necessary deflectors, soot scrapers, doors, dampers, etc. They have pressure gauges at feed water inlet, also feed water thermometers located one in pipe at entrance to economizers and one in pipe where water leaves the

Fig. 5. Roof of Plant, Showing Chimney and Cooling Tower.

same; also two gas flue thermometers reading to 1000° F. in smoke flue; one where gases enter economizers, and one where they leave. The necessary dampers are provided for sending the gases from the boilers either past the economizers and directly out the smokestack

or through the economizers and then up the stack, or through the economizers to mechanical draft fan and thence up the stack. The economizers as shown on the plans are located in the rear and above the boilers, supported upon a substantial iron framework and bricked in air-tight by 8-inch walls.

COAL AND ASH-HANDLING MACHINERY.

The coal and ash-handling plant is of simple and economical design, and consists of a system of cars, tracks, elevator and overhead ash bin. The cinders and ashes from the lower grates drop directly into a metallic ash hopper under each boiler. Running east and west immediately under these hoppers there is a narrow-gauge track. The ashes are dumped from these hoppers into small cars and pushed by hand along the track to an elevator, on which they are carried up and dumped into an overhead ash bin, from which they run by gravity into the wagons in the alley. Any ashes which accumulate in the stacks may be emptied directly in the cars in the same manner.

The entire space in front of the boilers in the basement is reserved for coal storage, the fuel being dumped through openings in boiler room floor. It is taken from this storage room in the same cars, tracks being provided the entire length of the coal storage space. It is then hoisted on the elevator to the floor above and distributed on tracks over the entire length of the boiler room in front of the boilers.

STEAM ENGINES.

There are now in operation two engines, Fig. 6, of the Williams vertical two-cylinder cross compound condensing automatic cut-off pattern, built by Wm. Tod & Co., of Youngstown, Ohio, and designed for direct connection to the dynamos and shafting. The east engine, No. 1, is of 750 indicated horse power, and is designed for driving one 500-kw. generator at the most economical rating of the engine when operated at a speed of 150 revolutions per minute, and supplied with steam at 170 pounds initial pressure per square inch at the throttle valve, and exhausting into a 24-inch vacuum. Engine No. 2 has double the capacity, and is similar in design to No. 1. The heavy fly-wheels are located between the A frames supporting the high and low-pressure cylinders. Each engine is so constructed as to be capable of operating continuously at double its rated capacity, and for short intervals only at one-third above its double rated capacity. This additional capacity is obtained by admitting live steam into the receiver or low-pressure cylinder. The high-pressure cylinders are steam-jacketed on the

barrel, and both cylinders on both top and bottom heads. The receiver is provided with reheating coils of copper. The main bearings are adjustable, and are provided with water jackets. The guides are water-jacketed on the running side. The cylinders and all bearings are lubricated by the Siegrist lubricating apparatus, which delivers the two kinds of oil to the cups under pressure automatically maintained by duplicate steam pumps. They also have hand oil pumps for additional safety. The cylinders have flat multiported valves driven directly from the eccentrics. The clearance is guaranteed not to exceed 6 per cent. in either cylinder. These engines are provided with shaft governors operating upon

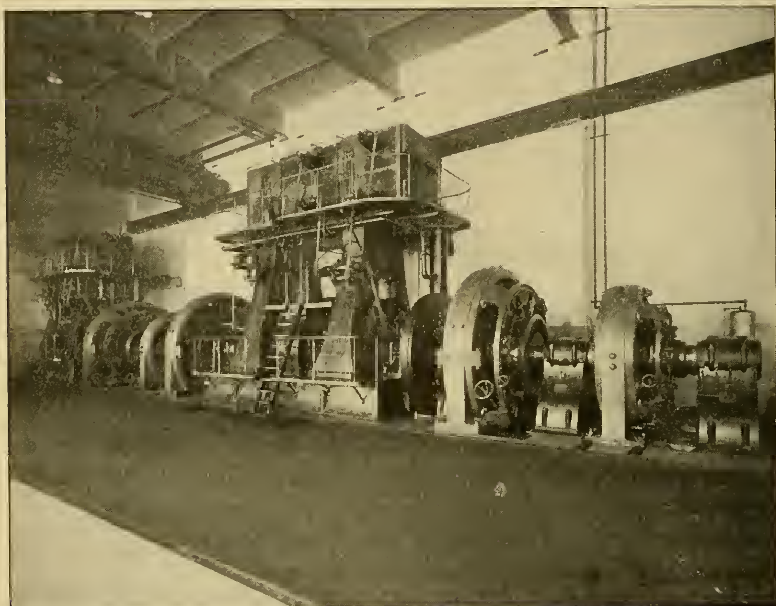


Fig. 6. Engines, Dynamos, Booster, Magnetic Clutches and Crane.

the valves of the high-pressure cylinders, and capable of varying the cut-off from 70 per cent. of the stroke back to minus $\frac{3}{16}$-inch opening. The regulation guarantees are that the drop in speed with a constant steam pressure from no load to one-third above rated load will not exceed $2\frac{1}{2}$ per cent. This guarantee also covers a variation of steam pressure between 160 and 175 pounds with constant load. The variation of speed will not exceed $3\frac{1}{2}$ per cent. with the combined changes in load and steam pressure above specified, either with or without the vacuum. The governor is also fitted with a special speeding device by means of which the engine

may be brought to the same rate of speed under friction only as under full load. When running with about 170 pounds pressure at the throttle, at 150 revolutions per minute and under a constant load at their rated capacity, the engines are guaranteed not to consume more than 15 pounds of water per indicated horse power hour.

Their principal dimensions: Engine No. 1—cylinders 18 inches and 40 inches x 30 inches; diameter steam pipe, 8 inches; exhaust, 15 inches; diameter crank shaft, 12 inches; length of bearings, 21 inches.

Engine No. 2—cylinders, 36 inches and 57 inches x 30 inches; steam pipe, 10 inches diameter; exhaust, 18 inches; diameter crank shaft, 16 inches; length of bearings, 28 inches.

Another 1500 horse power engine, designed and built by the Lake Erie Engineering Works, Buffalo, N. Y., has just been installed. Dimensions of cylinders, 23 inches and 48 inches x 36 inches; speed, 120 revolutions per minute.

CONDENSERS, PUMPS AND COOLING TOWER.

The condensing plant consists of one Worthington surface condenser, one Worthington cooling tower, two combined air and boiler feed pumps and two circulating pumps of the rotary type. The rated capacity of the plant is 33,750 pounds of steam per hour, but it will take care of overloads up to 49,500 pounds per hour with but slight reduction in vacuum. It is guaranteed to produce a vacuum of not less than 22 inches at above rating and under the worst conditions of service; 25 inches under fair and average conditions, and 26 inches under the best. These conditions vary with the humidity and temperature of the air. The condenser has 34,000 square feet of brass tube cooling surface.

The cooling tower, Fig. 7, located on roof is 18 feet diameter, 29 feet high and its filling or cooling surface is composed of galvanized iron pipe cylinders. It has duplicate fans located on opposite ends of the same shaft drawing air into the tower. These fans are driven by a belted motor in pent house on top of building.

There are two combined air and boiler feed pumps; one of sufficient capacity to handle the water required by the 1500 horse power engine, and the other of sufficient capacity for the 750 horse power engine, and two independent rotary circulating pumps of the same capacities. These pumps are driven by direct-geared motors, so designed that the speed may be varied at least $33\frac{1}{3}$ per cent.

There are also two injectors for reserve boiler feeds, each having a capacity of 11,250 pounds of water per hour, and capable of handling water of any temperature below 125° F.

FOUNDATIONS.

All the foundation work in this plant (except chimney) consists of one part Atlas Portland cement, three parts clean, sharp sand and seven parts crushed limestone small enough to pass through a $2\frac{1}{2}$-inch mesh. The brickwork used in foundations of

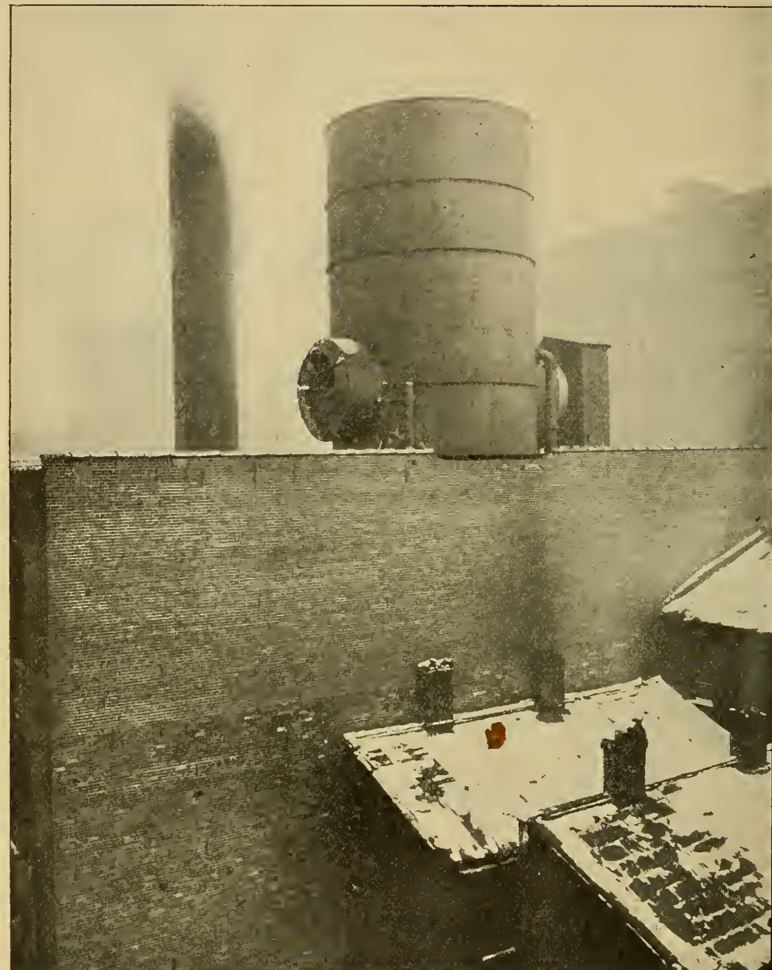


FIG. 7. COOLING TOWER.

chimney is composed of hard burned brick laid in cement mortar. The engine and generator foundations extend to a depth of 13 feet 6 inches below the floor line of the engine room, and form one large monolith extending the full length of the engine and generator machinery.

POWER TRANSMISSION SYSTEM.

The engines and generators are connected by means of a patented system of power transmission (see Fig. 6), consisting of quills and internal shafts with double bearings, connected by magnetic clutches. The arrangement is intended to make it possible to drive any one, two or all three of the 500-kw. generators, and either one or both of the boosters, from the large engine in case of accident to the small engine. Two generators and one booster may also be handled by the small engine in case of accident to the large one.

The generators are connected to the engines by means of magnetic couplings, so arranged that either intermediate generator or booster may be disconnected from one engine and connected to the other while all are in motion. When it is desired to start up a generator, it is brought up to speed as a motor and then connected to the engine by the magnetic clutches.

PIPE WORK.

The entire high-pressure system is designed to operate under a working pressure of 175 pounds per square inch, and was tested to 250 pounds hydrostatic pressure. All fittings are extra heavy. All pipe above 3 inches in diameter has flanged couplings and fittings. All bent pipes are made of steel, and bent hot and of long radius. All valves on live steam pipes and on the feed water connections under boiler pressure are bronze seated. All valves above 10 inches in diameter are by-passed. The cylinder jackets, reheaters, separators, steam headers and the entire pipe system is drained by means of the Holley system, returning the water directly to the boilers. There is a combined hot well and oil filter located between the condenser and boiler feed pumps. All the pipes are covered with magnesia. A steel exhaust pipe is provided for use when condensers are not in service, and extends through the roof near the stack. Each engine has a Cochran separating receiver located near the main throttle valve. Oil extractors are located between exhaust pipe and condensers. A suitable blow-off tank is provided and connected to boiler furnaces, oil extractors and other hot water drains, with suitable discharge to catch-basin, which in turn overflows to sewer.

CRANE.

The engine room is spanned by an electric traveling crane (shown in Fig. 6) with independent motors on the lifting, traveling and transfer motions. The capacity of the crane is 15 tons at 10 feet per minute, and it has a maximum speed of 30 feet per minute

at lighter loads. The maximum speed of travel is 80 feet per minute, and the maximum transfer speed 40 feet per minute. The motors are of 20, 15 and 5 horse power respectively, and are designed by the manufacturer as a part of the crane and built substantially into the framework of the structure. This crane has proved itself one of the most useful appliances about the plant.

GENERATORS AND BOOSTERS.

There are three 500-volt constant-potential electric generators, built by the Siemens & Halske Electric Company of America, of the internal ironclad-armature type. They are designed specially to

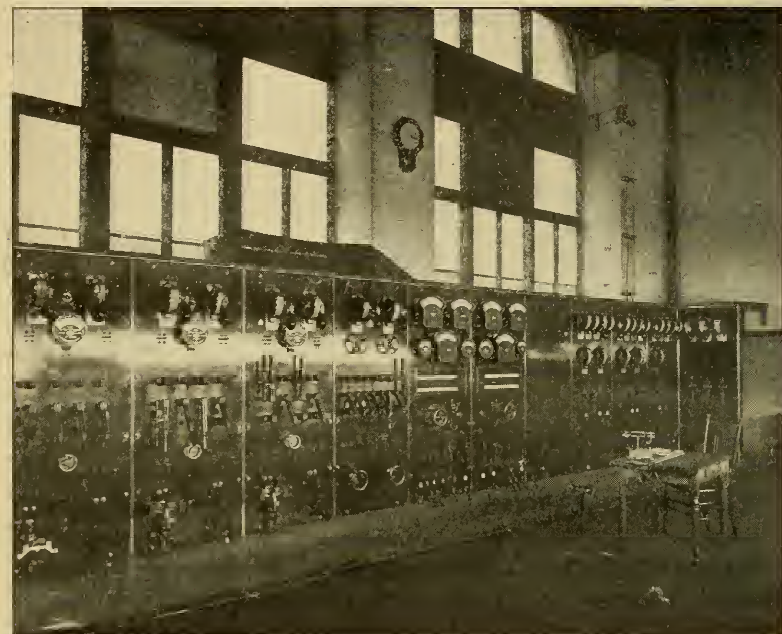


FIG. 8. SWITCHBOARD.

fit the system of power transmission adopted. The field frames of the generators may be slid parallel with the shaft a sufficient distance for reaching the armature for repairs. The capacity of each generator is 500 kw. at 525 volts when operated at 150 revolutions per minute. At this rating the rise in temperature of the armature will not exceed 40° C.; of the field, 35° C.; of the commutator 50° C. The generators are guaranteed for an overload of 25 per cent. for two hours, and $33\frac{1}{3}$ per cent. for one hour, with a 50 per cent. momentary overload without injurious sparking. They will not flash at the commutator when the circuit breaker opens at 50 per

cent. overload. The commutators are of large diameter, insulated with mica and designed for carbon brushes. The brushes are proportioned for 25 amperes per square inch of contact with rated load, and have hand wheels for both adjusting and lifting. One megohm of insulation resistance is specified between conductors and frame. The guaranteed efficiencies of these generators are as follows:

At ¼ load	88	per cent.
At ½ load	92½	"
At ¾ load	93½	"
At full load	94	"
At 25 per cent. overload	93	"

There are two separately excited shunt wound boosters, each of 50-kw. capacity at 150 revolutions per minute, and capable of carrying 500 amperes and delivering any voltage from zero to 130 volts. The boosters are of the same general construction and design as the generators, except that the field frames are divided vertically. Two more generators of the same capacity are being made at present by the same company.

SWITCHBOARD.

The plant contains a composite switchboard, Fig. 8, of 2-inch black marbleized slate, containing three generator panels, one booster panel, two battery panels, one wattmeter panel, three feeder panels and one voltmeter panel. These are carried upon an angle iron frame standing directly upon the floor. Each generator panel contains two pilot lamps, one dynamo galvanometer, one 1500-ampere amperemeter, one 600-volt voltmeter, one single pole circuit breaker, one dynamo field rheostat, three single pole double throw 1500-ampere switches and one single pole single throw switch. Each generator panel also contains one special Don Shea patent field switch, so that generators may be operated either bus-exciting or self-exciting, as desired.

The booster panels contain the two rheostat handles for the booster field regulators, two amperemeters and the necessary single and double pole switches for the proper operation of the plant.

On the battery panels of the board the following instruments are mounted: Two 1200-ampere double reading amperemeters, four 600-ampere double reading amperemeters, two 300-volt round pattern voltmeters, two 5-volt round pattern voltmeters, two 50-point voltmeter switches, four end cell switch indicators, four sets of motor contact switches for operating motors on end cell switches, which are located in the battery room, and the necessary single pole single throw switches for making the necessary connec-

tions between battery, bus-bar and boosters. There are four end cell regulating switches located in the battery room, each of 600 amperes capacity, with points for connecting fifty end cells. Each switch is provided with a motor and gearing which are operated from the battery panel of main switchboard, and the position of the contact switch is shown at all times by the end cell indicators on switchboard. These switches may be operated by hand if desired,

Fig. 9. Storage Battery.

with the motor completely disconnected. Each motor is capable of handling the two end cell switches on each side of the circuit, although in practice the two are operated in multiple during times of heavy discharges.

The wattmeter panel is unfinished at present, but is designed to carry when completed four 6500-ampere 250-volt wattmeters.

Upon the feeder panels five feeders are connected, each having an amperemeter and double throw single pole switch of 1500-ampere capacity on the positive and negative sides and a double reading amperemeter and single throw single pole switch of 500-ampere capacity on the neutral cable. The voltmeter panel carries one 500-volt voltmeter and two 250-volt voltmeters, each with a suitable switch for connecting to the various pressure wires. Each

panel on the board is surrounded by an ornamental copper molding, and is lighted by two incandescent lamps. All amperemeters and voltmeters except those on the battery panels are edgewise instruments.

There are four bus-bars on the switchboard; one high positive, one low positive; one high negative, and one low negative. There are also positive and negative charging busses. The generators are so arranged that each generator may be operated on either high or low bus-bars, either in multiple or separately. For convenience in handling, the right-hand switches are made positive, and the upper throw of switches connects to the high bus. Each of the two end cell switches on each end of the battery may connect either to the high bus or low bus, or to the charging bus. The two boosters in the plant may each be connected either between high bus and charging bus, low bus and charging bus, or between low bus and high bus, on either side of the system. The boosters may be connected in series either between low positive bus and neutral or between low negative and neutral. These combinations provide for charging the battery under all conditions of service, and at the same time maintaining it upon the line as an equalizer of the pressure. Also, either side of the battery may be completely disconnected, or the entire battery cut out of service and the balance of the system maintained by means of the two boosters connected together in series and operating between the neutral and either side of the system.

All the electric connections between generator and booster and switchboard are made of asbestos-covered copper cable run underneath the floors and supported upon porcelain holders. The connections between battery and switchboard are made by means of copper bars, lead-covered and painted with an acid-proof paint, and supported upon porcelain racks. The battery is connected through switches to the bus-bars and outside circuits without the intervention of either fuse or circuit breaker. Two additional generator panels of the same design have lately been added to take care of the additional dynamos contracted for.

STORAGE BATTERY.

There are 280 cells, Fig. 9, of the Electric Storage Battery Company's accumulators, each containing thirteen positive Manchester type plates and fourteen negative chloride plates. These are contained in lead-lined wooden tanks which are supported on large porcelain insulators resting upon 4 x 6-inch beams. The elements themselves in each cell rest upon heavy glass plates, and

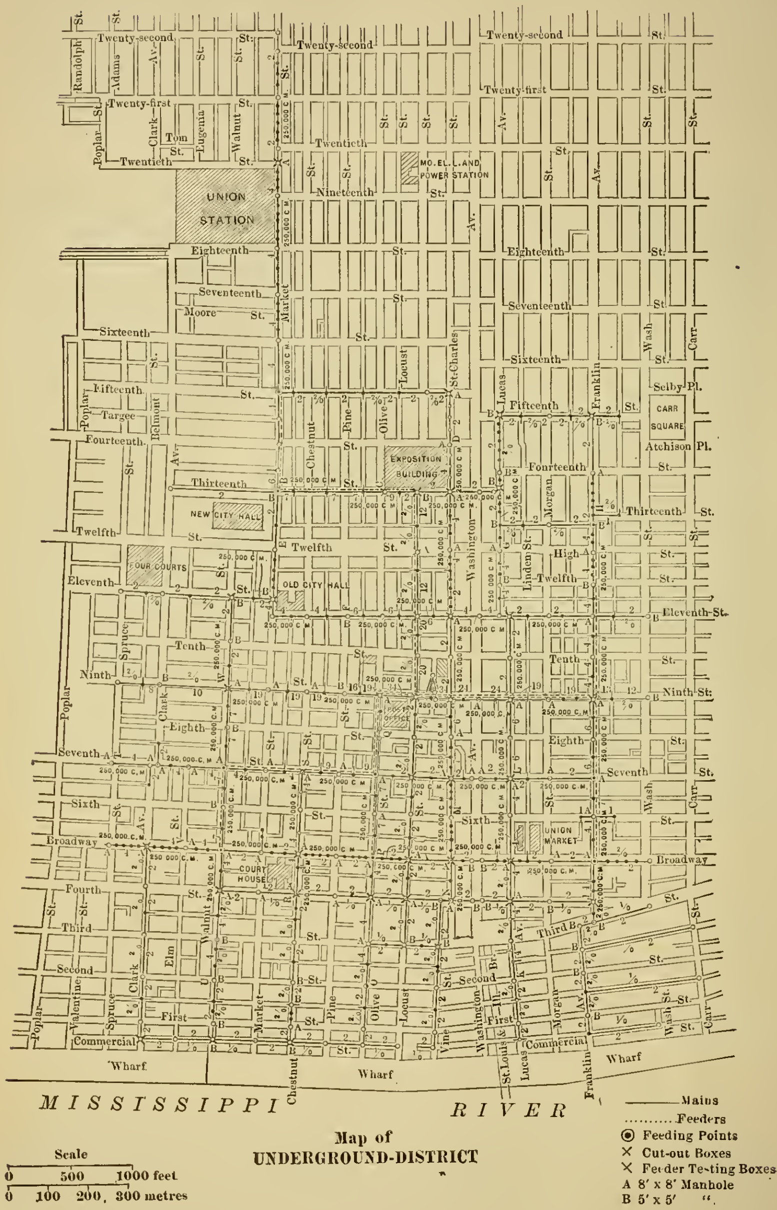

MISSISSIPPI RIVER
Map of
UNDERGROUND-DISTRICT
Scale
0 500 1000 feet
0 100 200 300 metres
——— Mains
.... Feeders
⦿ Feeding Points
× Cut-out Boxes
× Feeder Testing Boxes
A 8′ x 8′ Manhole
B 5′ x 5′ "

FIG. 10.

are separated from each other by glass tubes. The capacity of this battery is 2000 ampere hours at a discharge rate of 250 amperes, and it is capable of maintaining a maximum discharge rate of 1000 amperes for one hour. It is guaranteed to give a discharge of 500 kw. for one hour without a drop in pressure below 1.7 volts per cell. The normal charging rate is 250 amperes, and the maximum charging rate 350 amperes.

The battery as mentioned above is located in the basement, partly under the engine room, partly under the sidewalk, in a cool, well-ventilated room. The floor is composed of vitrified tile laid in pitch upon a concrete base.

CONDUIT SYSTEM.

Many were the criticisms hurled at the heads of the city officials when they declared that all of the high-tension electric companies should occupy jointly a single conduit system. However, the city proceeded upon this line, and issued conduit rights to all the high-tension companies to the ownership of so many ducts each in a joint underground conduit system occupying one side of the street. On the opposite side the low-tension conduits of the telegraph and telephone companies were placed.

It was feared that the joint building, ownership and maintenance of a conduit system by the high-tension companies might lead to endless litigation, but a liberal application of the "Golden Rule" to the grouping of ducts and to the location of service boxes and other engineering details of the work has produced a system of underground conduits which we believe has few, if any, equals.

The high-tension conduits system consists of 3-inch cement-lined pipe laid on $5\frac{1}{4}$-inch centers, with 1 inch of concrete between pipes and 3 inches surrounding the entire group. All ducts are laid to drain to manholes. The top layer of ducts enter service boxes, which are of two sizes, 3 x 3 feet and 3 x 4 feet. Service boxes are placed at most convenient points for reaching customers, and their depth is governed by the depth of the conduit at each location. Manholes (Fig. 11) located at every street intersection, and oftener where necessary, are of three sizes, 4 x 4 feet, with 9-inch walls; 5 x 5 feet, with 9-inch walls, and 8 x 8 feet, with 13-inch walls. In depth they are all designed to be 6 feet 6 inches in the clear under the roof. They are connected to sewers wherever sewers could be reached.

The conduit system of the Imperial Electric Light, Heat and Power Company is shown on map, Fig. 10, which gives the location of the power plant, the number of ducts owned by this com-

pany in the joint conduit on each street and the location of all manholes and service boxes. It will be observed that the main trunk line runs east on Olive street and west on Locust street. The north and south trunk line is on Ninth street. The conduits as a rule occupy every other street in each direction. They were laid out with the object in view of being able to reach one end of every alley in the city with the distributing main. It was the intention to build service boxes only opposite the entrance of alleys and to distribute entirely through the alleys either by overhead pole lines or through underground distributing laterals.

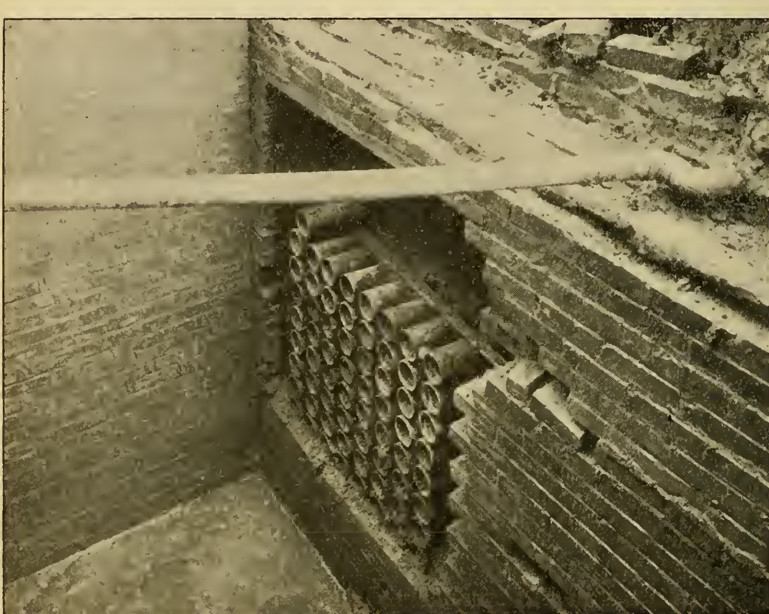


Fig. 11. Manhole of Underground System Showing Ducts During Construction.

The conduit system contemplates twenty-three feeding points, which are shown on the map marked with the letters from A to V, inclusive. The entire distribution system consists of two ducts, providing one duct for a three-conductor cable and one extra duct for city lighting or other service in the future.

Where feeders were located the number of ducts was increased to provide for them. The system as planned provides for feeders of sufficient size so that one of the largest cables would fill one duct, taking a single cable for the positive and another for the negative sides of the system. A third duct would contain the neutral feeder

and pressure wires. Another duct to contain the three-conductor main cable, and one duct reserved for future service.

UNDERGROUND CABLE SYSTEM.

While the conduit system provides space for a total of twenty-three feeders, there have been but five installed at present. They run from the power house to the points B, H, D, P and V on the first map. The map shown in Fig. 10 gives the location of these feeders, the testing boxes, pressure wires, three-conductor mains, junction boxes and lateral service cables. Each feeder consists of two 1,500,000 C.M. single conductor cables and one 500,000 C.M. single conductor cable for the neutral wire. A pressure wire of No. 16 three-conductor cable carried in the same duct with the neutral, and connected to the ends of the feeder, provides means for measuring the pressure at the feeding point by a voltmeter located at the plant. The 1,500,000 C.M. cable is made up of 127 strands of No. 10 B. & S. gauge copper, insulated with $\frac{5}{32}$-inch rubber and protected by $\frac{1}{8}$-inch covering of lead. The 500,000 C.M. cable is composed of 61 strands of No. 11 B. & S. copper, insulated with $\frac{4}{32}$-inch rubber, protected by $\frac{1}{10}$-inch lead sheath. The No. 16 three-conductor pressure cable is a solid copper conductor, with $\frac{1}{16}$-inch rubber and $\frac{1}{16}$-inch lead. The neutral conductor is only one-third the size of each of the other wires, since the entire motor business supplied by the company is connected directly to the positive and negative wires, and does not affect the load upon the neutral. It will also be observed that the feeder cables have all the same carrying capacity, notwithstanding the fact that some are nearly twice the length of others. The object of this is to economize conduit space and cost of cables by using the largest cable that can be conveniently pulled through a duct. Provision is made at the plant for keeping the pressure at the ends of all these feeders approximately equal, regardless of their length and the variation in drop, by running different voltages at the switchboard.

Each of these feeder cables connects to a single pole double throw switch on the switchboard without the introduction of any fuses or circuit breakers. Each feeder goes through two feeder testing boxes placed at convenient distances along its length, and at the end connects to the system of mains through copper fuses located in the junction boxes.

The system of mains shown on the map consists of three-conductor cables of three different sizes. No. 1-0 is used where service is lighter, and No. 2-0 where heavier, and 250,000 C.M. where

heaviest. The No. 1-0 three-conductor cables consist of 19 strands of No. 15 B. & S. copper, insulated with $\frac{3}{32}$-inch rubber. The No. 2-0 has 37 strands No. 15 B. & S. copper and the same thickness, $\frac{3}{32}$-inch, of rubber. The 250,000 C.M. cable has 37 strands No. 12 B. & S., with $\frac{7}{64}$-inch rubber. All three sizes of three-conductor main cables have $\frac{1}{8}$-inch lead cover.

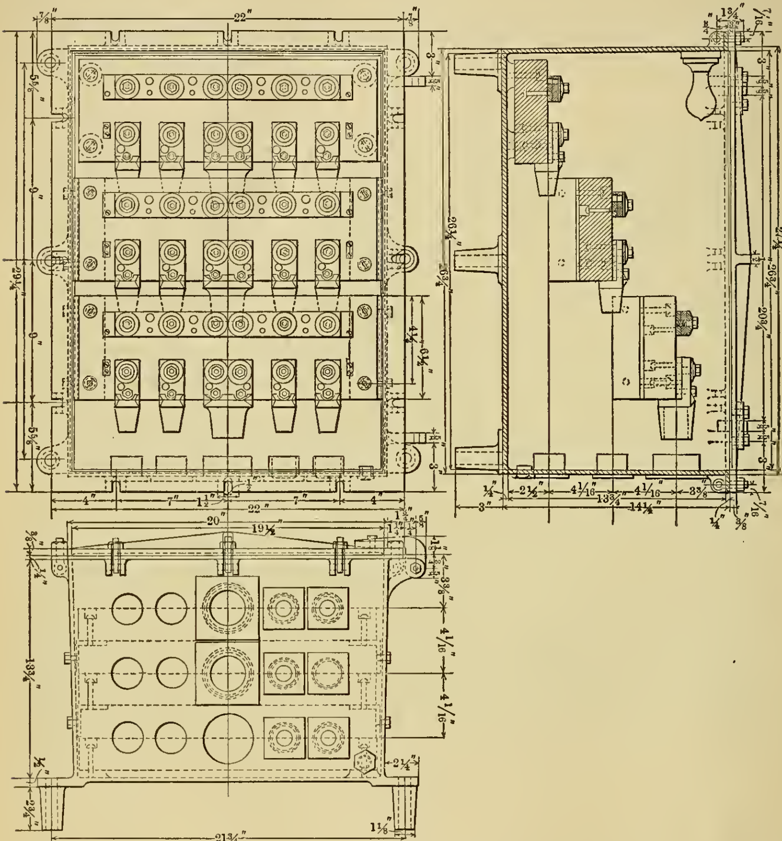


FIG. 12. FIVE-WAY JUNCTION BOX. SCALE 1-12 SIZE.

The mains are composed of three conductors, each of the same size, to provide for better distribution of pressure. The rubber tape surrounding each conductor was made of a distinguishing color for convenience in connecting, and very few errors of this kind were made in connecting together the entire system. At the points shown on the map junction boxes were placed, which are shown in detail in Fig. 12, into which these three-conductor mains

were run and connected to bus-bars through copper fuses. These fuses are each provided with a small porcelain knob for convenience and safety in handling while fusing up or disconnecting. The lead sheaths on the mains were divided and brought up through the bottom of the junction boxes and sealed water-tight by means of special stuffing boxes. The lead joint at the point of division outside the box was wiped water-tight. The cover of the junction box is screwed tight upon a rubber gasket by toggle bolts, making a thoroughly water-tight box.

The feeder testing boxes referred to above are similar in design to the junction boxes as shown in Fig. 12, although somewhat smaller and not so deep. They provide convenient means for opening the feeders for testing, the location of trouble or the making of repairs. Connection is made in these boxes by heavy copper links, which are not in any case intended to act as fuses.

The lateral service cables connecting from the underground mains to the basement of the customers' building are similar in design to the three-conductor mains, differing only in size and corresponding variation in thickness of rubber and lead. They are joined to the mains in the service boxes by means of a three-conductor soldered joint, which is carefully insulated with rubber, thoroughly taped and protected by a cast iron box. This box is then filled with an osokerite compound, thoroughly insulating and preserving the joint from all contact with moisture or other deteriorating substance. The insulation resistances of these cables were guaranteed as follows:

No. 16 B. & S. three-conductor, 1000 megohms per mile.
No. 0, 2-0 and 250,000 C.M. three-conductor, 750 megohms per mile.
500,000 C.M. single conductor, 500 megohms per mile.
1,500,000 C.M. single conductor, 400 megohms per mile.

For a break-down test the entire system was submitted to 3000 volts alternating current, and found to withstand this test satisfactorily. The insulation guarantees were also found satisfactory under accurate tests.

The insulation resistances were all measured by means of the capillary electrometer designed by H. C. Burgess, of the University of Wisconsin, and described by him at the Omaha meeting of the A. I. E. E. The results were found to be highly satisfactory. It is an extremely sensitive instrument, but is unaffected by magnetic influences or by the jarring of building. The only precaution found necessary was the great care essential to avoid surface leakage. Resistances were measured as high as 2000 meghoms.

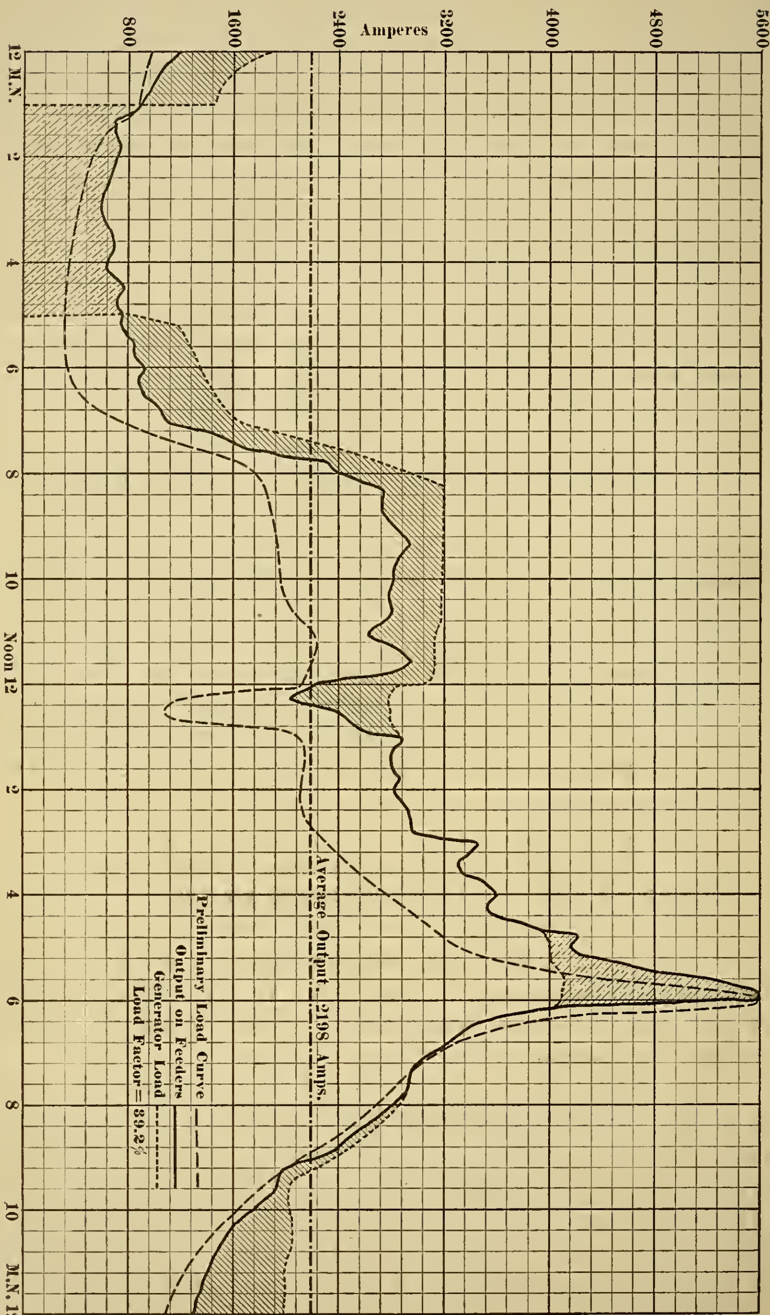


FIG. 13. LOAD CURVES, SHOWING ORIGINAL HYPOTHETICAL CURVE AND PRESENT ACTUAL CURVE WITH THE USE OF BOXES.

The voltage used throughout most of the tests was 100 volts, obtained from a chloride of silver battery. Attempts were made to use a dynamo current from the local power circuits, thus making the test at 500 volts the maximum pressure intended to be carried in use. The attempt was a failure, due to the unsteadiness of the local power circuit and the consequent disturbance due to condenser effect in the cables. This instrument can be put to a variety of uses, although we believe this is the first instance where it has been used commercially for testing an entire system of underground cables. We have checked its results very closely with a galvanometer, using the deflection method, but the annoyance and delay incidental to the use of the galvanometer in this work prevented more than a very occasional checking.

INSIDE WIRING.

The entire inside wiring is done on the two-wire multiple arc plan. The lateral cables entering the basements of the customers' buildings are three-conductor cables, furnishing a constant potential supply of electricity at either 235 or 470 volts. All electric power service is connected to 470 volts, and the inside wiring is run open and supported on porcelain knobs, with rubber-covered wire. The incandescent and arc lamp wiring is taken off one or the other side of the system at 235 volts and run with rubber-covered wire either on porcelain knobs or cleats or concealed in an approved conduit system. All of the old-style 110-volt cut-outs were replaced. Specially designed tablet boards with terminals properly spaced for the higher voltages, and with inclosed fuses, were used throughout this work. All of the old sockets were replaced with the latest design of porcelain sockets, and where defective cord was observed it was replaced by an approved rubber-covered flexible cord. All of the inside wiring having been gone over in this way, and cleared of grounds and brought up to the latest standard of practice, has resulted in decreasing, rather than increasing, the fire risk following the introduction of the higher voltage system.

INCANDESCENT LAMPS.

The incandescent lamps used on this system are of the 235-volt type, mostly of 16 C.P., although some 10 C.P. and some 32 C.P. are in use. Also small candle power decorative series lamps. The lamps are all Westinghouse cap and porcelain base. The filaments are either double, two in series, or coiled in several convolutions. This characteristic is due to the extra length necessary on

a lamp of this voltage. The lamps were bought under guarantees regarding efficiency, life and the maintenance of candle power, which were entirely satisfactory to the purchaser. In practical operation the light has been entirely satisfactory to customers, and they compliment the character of incandescent service furnished. There were at first minor mechanical and electrical defects, however, such as the sagging of the filament until it touches the glass where lamps are not placed in a vertical position, and the short-circuiting of leading-in wires when a filament burns out near its support, all of which have been remedied in later lamps. There have, however, been no accidents or fires resulting from these causes.

ARC LAMPS.

In the original design of this plant, begun fully three years ago, it was anticipated that its principal business would be power service, and that arc lighting would not exceed 15 per cent. of the total service. The introduction, however, of the inclosed arc lamp and its remarkable popularity, due to the steadiness of the light and the facility with which its service is metered, has so increased the demand for arc lighting that the arc service is at present a very important part of the company's business. It was believed at the time that the plant was designed that arc lighting might be made secondary to both the incandescent and motor work. The 235-volt inclosed arc lamp was therefore adopted on account of its convenience, one light being controlled independent of all others. It has been found by experience that two arc lamps burning in series on 235 volts give better service than the single lamp. In cases where a single lamp must be used a satisfactory light has been obtained by increasing the current to $3\frac{1}{2}$ amperes.

MOTOR SERVICE.

The entire power service is taken from the outside wires of the system at 470 volts. These wires inside of the building in all cases are treated as high-tension circuits. It might be surmised that complaint would be made regarding the power service on account of this reduction of voltage on 500-volt motors. This has not proved to be the case. The motors having been previously used upon systems varying in voltage from 450 to 550, the users of power were educated to expect a considerable variation in the speed of their motors. With a steady pressure of 470 volts at the motor terminals, none of the company's customers have complained regarding their power service.

LOAD CURVE.

It may be interesting to submit a preliminary load curve of this plant, prepared by the engineers and submitted to the company two years and a half ago, and to compare it with an average load curve of the plant at present. We have reduced the scale of the former and plotted them side by side on the same sheet. These curves are shown in Fig. 13. Their correspondence in shape is interesting. Their points of difference are explained by the increase in the arc business above referred to. This curve also shows one of the great advantages of the storage battery. The entire plant is shut down from one o'clock until five in the morning, and the load carried upon the battery. The machinery is then started and the battery charged during the forenoon, allowed to float upon the system during the afternoon and discharged during the peak in the evening, as shown upon the shaded portion of the curve; and again charged considerably during the first half of the night before shutting down. Interesting features are the large all-night load and the comparatively low peak or maximum load. The average output for twenty-four hours is 2198 amperes, which is 39.27 per cent. of the maximum load.

SPECIAL FEATURES.

The distinguishing features of this plant which marked it as advanced engineering practice are:

First. The 220-440-volt system of distribution.

Second. The entire system is underground.

Third. The battery equalizer and auxiliary.

Fourth. All subsidiary apparatus is electrically driven.

Fifth. Fuel economizers with induced mechanical draft.

Sixth. Condensing apparatus with cooling tower.

(a) The wisdom of selecting the double voltage system will be appreciated when it is stated that the saving in copper alone in the district covered by this plant is equal to half the cost of the building and entire station equipment. This system was almost unknown at the time of its adoption here, but several plants using it have since then begun operation in Europe, and another large installation is being erected in this country. The system is reliable, safe and satisfactory in its service to the public.

(b) The undergrounding of all wires is the ideal method of distribution as regards public safety, reliability of service and low depreciation and repairs.

(c) The value of a storage battery as an equalizer of pressure and as an auxiliary to the steam plant is universally admitted. It

has proved indispensable on many occasions in this plant. Its readiness to take all burdens thrown upon it, whether accident to plant, short circuit in underground cables or sudden demand for light caused by a thunder storm, needs only to be experienced to be appreciated.

(d) Driving all boiler feed, circulating and air pumps, elevator, fans, etc., by electric motors saves the condensation in all subsidiary steam pipes, as well as avoids the wasteful use of steam incident to this class of apparatus. By using steam only in the large cylinders of the compound condensing engines and driving all minor apparatus by motors, it is estimated that a saving of about 10 per cent. on the entire output of the plant is realized.

(e) Fuel economizers give all the water entering the boilers an additional temperature of 100° F., which effects a saving of about 9 per cent. in the use of fuel. With coal at $1.50 per ton, they will earn annually about 25 per cent. on their cost.

(f) With all losses deducted, it appears that condensing apparatus as here employed make a saving of from 15 to 20 per cent. in fuel, thus earning a large return on its cost.

The entire station equipment was included in one contract, under rigid guarantees from the contractor covering the efficiency of the plant as a whole. A definite cost of coal per kilowatt hour delivered to outside circuits from the switchboard was guaranteed under a forfeiture in case of failure, with an equal bonus for increased efficiency above the figure specified. It was intended to give in this paper the results of these tests, but, as they are not completed, no report can as yet be made.

ASSOCIATION

OF

ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXIII. NOVEMBER, 1899. No. 5.

ALTERNATING-CURRENT POWER MOTORS.

BY W. A. LAYMAN, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, April 5, 1899.*]

COMMERCIAL applications of the electric current are broadly divided between, first, those involving direct current; second, those involving alternating current. Both forms of current are so well understood, and the development of apparatus for the utilization of them is so well advanced, that, within certain limitations, either may be used for a great variety of purposes. Examples of this are to be found in arc lighting, incandescent lighting, power motor work, street railway service, electric heating apparatus, etc. It cannot be said that either form of current can be used with equal *facility* and *economy* in these several directions, but development has advanced to such a point that prominent electrical men are not able to agree on the exact dividing line where the advantage of one form of current ends and that of the other begins. Remarkable strides have been made in alternating-current applications, and results are now accomplished with this current that a few years ago were declared not only improbable, but impossible. Notably is this the case in the power motor field. A decade ago the alternating-current motor was little more than a laboratory plaything; to-day its practical and efficient adaptability to power work of all kinds is generally conceded.

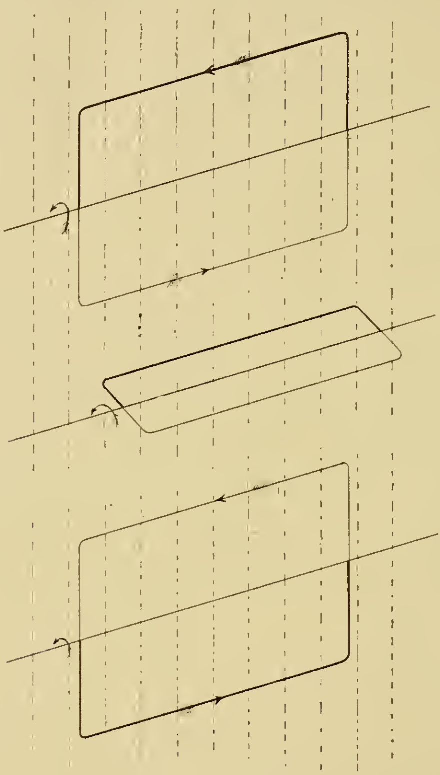
It may be incidentally recalled that there was much controversy as to whether the great Niagara plant should generate direct or alternating currents, all arising from the claim that there was no certainty of ever having a commercially practicable alternating-

*Manuscript received October 4, 1899.—Secretary, Ass'n of Eng. Socs.

current power motor. To-day this power plant is generating forty to sixty thousand horse power, all in alternating current, and a large part finds application in power motor fields.

(A) DIFFERENCE BETWEEN DIRECT AND ALTERNATING CURRENTS.

If there exists in a given space what is termed a magnetic field, and if an electrical conductor is quickly moved across this space in a direction angular to the direction of the magnetic lines of force, as they are technically called, an electric pressure is generated in



FIGS. 1, 2 AND 3.

this conductor; and if the conductor is a closed loop, under proper conditions as to algebraic relation of the pressures created, an electric current will flow around the loop.

In Fig. 1 such a magnetic field, with a loop of wire revolving in it, is shown. Here the plane of the loop is parallel to the direction of the lines of force, and in its rotation, in the direction indicated by the arrow below the figure, the loop is cutting across the lines of force and generating a current flow, as shown by the two

arrow-heads on the sides of the figure itself. In this position the loop is cutting these lines of force at the maximum rate of speed, and therefore generating its maximum pressure. As the plane of the loop revolves toward a position at right angles to the lines of force the rate of cutting decreases, and when the horizontal position is reached, as in Fig. 2, this rate of cutting is zero. As the rotation further continues (Fig. 3), the sides of the loop begin to cut the lines of force in the reverse direction, thus generating pressures and

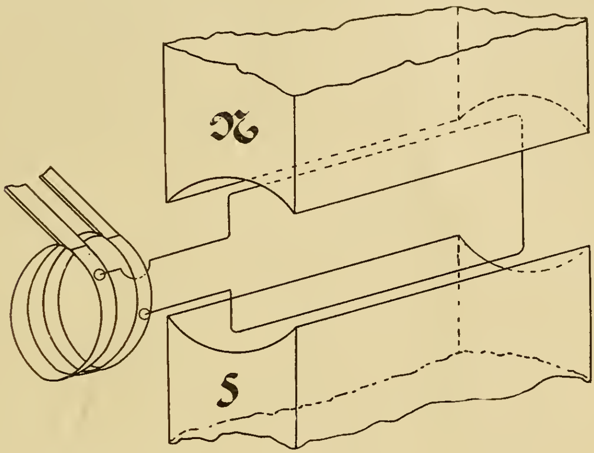


Fig. 4.

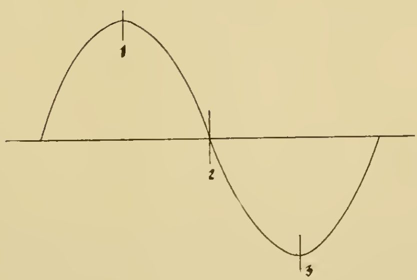


Fig. 5.

currents of opposite sign to those in Fig. 1, as indicated by the arrow-heads.

It is apparent that a loop so revolving generates a pressure and also a current wave which changes sign as the cutting, relative to the direction of the lines of force, is changed, rising slowly from zero to a maximum positive, and then back through zero to a maximum negative. Such a wave, diagrammatically plotted with reference to time, is shown in Fig. 5.

Figs. 4 and 6 illustrate an extension of this principle to the dynamo electric machine. N and S represent the magnetic poles, in the space between which there exists a strong magnetic field. The loop of wire in Fig. 1 now becomes the revolving armature. Instead of being closed upon itself, however, it is open at one end, and the open ends are connected to revolving rings. Upon these rings brushes bear which carry the current out into the exterior circuit and back again. Through such an exterior circuit, with the construction shown in Fig. 4, a true alternating current would flow, as is shown in Fig. 5. If in such a dynamo the loop revolves at the rate of eight thousand complete turns per minute, the cur-

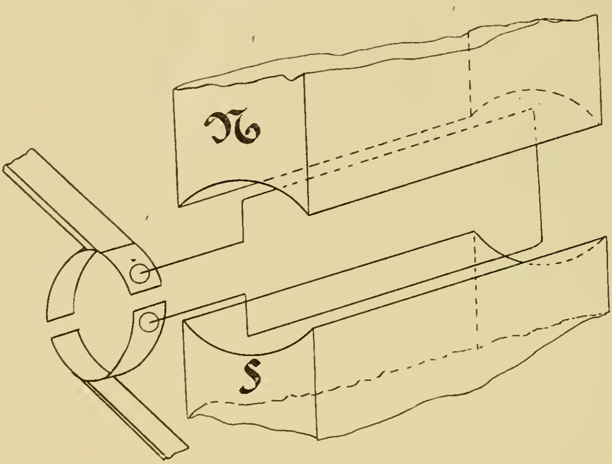


FIG. 6.

FIG. 7.

rent will be one of sixteen thousand alternations, or half waves, per minute, which is one of the standard frequencies of commercial alternating current of to-day.

To produce direct current, or current in which the flow is always in one direction, and of practically constant magnitude, it is necessary only to substitute for the two revolving rings of Fig. 4 one split ring, as shown in Fig. 6. By so placing the brushes (bearing upon the two half rings) as to cause them to stand on the breaks in the ring when the armature loop is in the zero generating position, a reversal of the negative portion of the alternating wave of Fig. 5, in so far as the external circuit goes, is accomplished.

By this reversal a single loop of wire would generate a form of current such as is illustrated in Fig. 7. This would be uni-directional, but pulsatory in character. To reduce this from such a form to a true direct or constant-pressure uni-directional current requires but a multiplication of generating loops, the commutator being still further subdivided to provide two connections for each loop. The external circuit is therefore in contact with the ends of any one loop through a small portion of a revolution only, and the effect is to send out into the circuit only the high-pressure sections of a great many waves, as shown in Fig. 8.

If it were desired to generate two independent alternating-current waves, this might be done by introducing independent armature loops, displaced from each other by a definite angle. If this angle were 90°, two such loops would generate pressures in quadra-

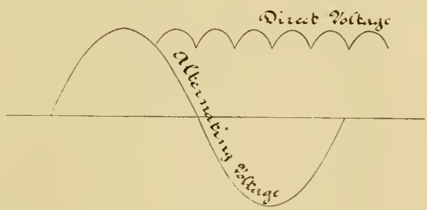


FIG. 8.

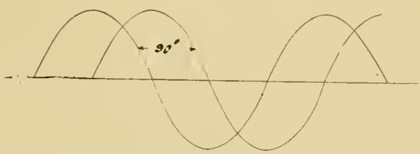


FIG. 9.

ture, or differing in phase by 90°. Such waves, plotted, would near the relation shown in Fig. 9. Similarly, three independent loops set at 60° to each other would be made to generate, by proper connections, currents differing in phase by 120°, as shown in Fig. 10. In this manner are produced the two-phase and three-phase currents of practical application to-day, these currents being illustrated in Figs. 9 and 10 respectively.

(B) DIRECT- AND ALTERNATING-CURRENT MOTORS.

Similarly, I may briefly discuss the fundamental differences between direct- and alternating-current motors.

A very early development in the application of electric current was the discovery that both forms of dynamo, as shown in Figs. 4 and 6, were reversible in process. That is, with a given magnetic field and a source of current from the outside, each form of arma-

ture would, with its corresponding form of current supply, run as a motor *under proper conditions.* With Fig. 6 the limiting condition was that the brushes should be so set upon the commutator as to send the direct current into any given armature loop at that instant when this loop occupied such an angular position with reference to the direction of the lines of force of the magnetic field as to provide a turning couple between the lines of force and the loop, this action arising from the fundamental consideration that magnetic lines of force attract or repel conductors carrying electric currents, according to the direction of the flow of the current in the conductor.

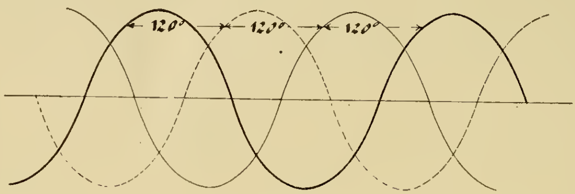


FIG. 10.

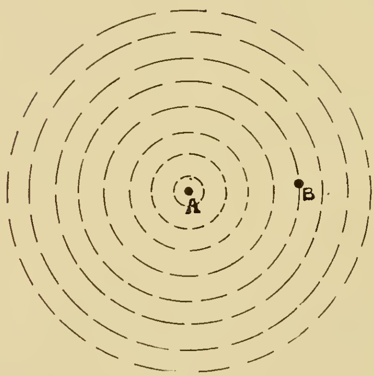


FIG. 11.

In Fig. 4 the limiting condition was to have the loop revolving at such a rate as to cause it to move into the position of reverse cutting of lines of force simultaneously with the change of direction of flow of the current supply. In other words, the loop had to revolve in step with the alternations of the current supply, otherwise the attractive and repellent forces would neutralize or interfere with each other. Such a motor, therefore, had to be brought up to synchronous speed, as it is termed, before it would run with load. For several reasons, other than this great disadvantage of

not being able to start, the synchronous motor was not deemed commercially practicable for power work in general, and even to-day has only limited uses.

The next step was to endeavor to make an alternating-current motor along the lines of Fig. 6. In other words, it was attempted to use the direct-current motor on alternating currents. Since the direction of rotation of the armature of a direct-current motor is the same, so long as the relation between the armature windings and the field windings remains unchanged, it was assumed that the motor could be easily used on alternating currents.

If sudden changes of direction of the current were to occur at long intervals of time apart no serious consequence would result, and the motor might prove satisfactory; but with periodic changes of direction of great rapidity, such as would exist with an alternat-

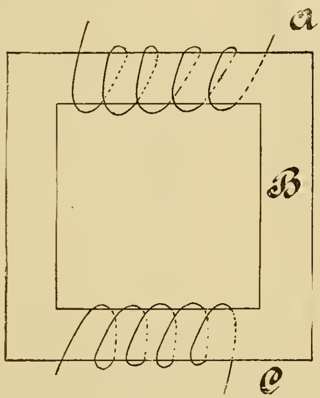


FIG. 12.

ing current, a new element is introduced. *With an alternating magnetic field currents may be generated in stationary coils of wire.* An electric current flowing through any wire sets up a magnetic field around the wire. If this current is alternating, an alternating field follows, the lines of force expanding and contracting in concentric circles with each alternation of the current. Such a field is shown in Fig. 11, A being the conductor through which flows the current producing the field. If a second conductor, as B, is brought into this field the expanding and contracting lines of force cut across B, and by this cutting induce alternating currents in B.

An application of this principle is found in the static transformer. When a coil of wire A, as in Fig. 12, is wound upon an iron core B, and at another point on this iron core a second coil C is wound, an alternating current flowing in A sets up alternating lines of force, which are, by reason of its magnetic conductivity

being better than that of air, drawn into B. These lines of force generate an alternating current in C, hence the dynamo (for the transformer is a dynamo) has in this instance its armature C stationary while the magnetism revolves.

It is largely this transformer action which makes the direct-current motor a failure when operated on alternating currents. The effect of this action may be seen in Fig. 13. The coil C, which is a portion of the armature winding, is in the position where, by its rotation alone, it is generating no electrical pressure, and therefore supplying no current to the outside line. In a direct-current motor, where the magnetic field is constant, this wire is practically dead at this instant, and the brush bearing upon the two commutator bars which are connected to the ends of these loops of wire, notwithstanding that it short-circuits this coil for an instant, causes no sparking.

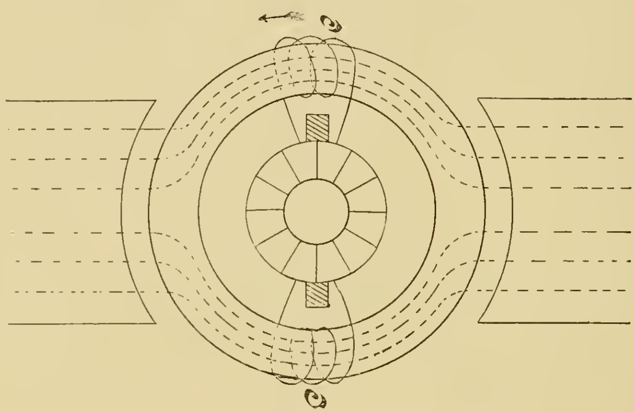


FIG. 13.

With an alternating magnetism, however, the coil is in position to act as the secondary of a transformer, and the short circuit through the brush causes a current flow which produces a spark when the brush passes onto the succeeding segments of the commutator. This sparking is such as to make continuous operation in this manner impracticable.

Alternating-current motors, therefore, remained a practical failure until an entirely new principle of operation was discovered. This was the principle of the so-called induction motor. The induction motor is a species of alternating-current transformer. It corresponds to the transformer in having the three elements of (1) a *primary winding,* into which current is fed from the supply circuits; (2) *an iron circuit,* or *series of circuits,* in which alternating

magnetism is set up by the current flowing in the primary winding, and (3) a *secondary winding,* in which currents are induced as it cuts the magnetic lines of force produced by the primary winding. This primary winding corresponds to the *field winding* of the direct-

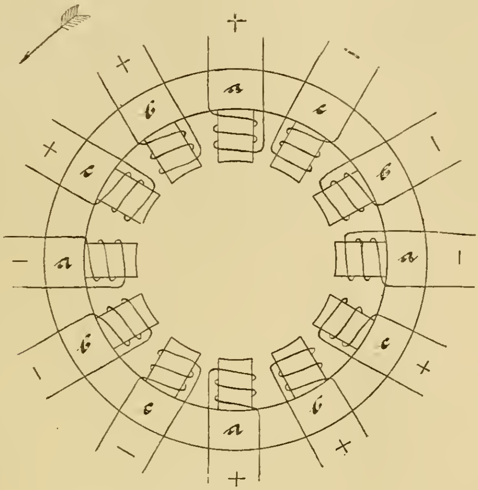


FIG. 14.

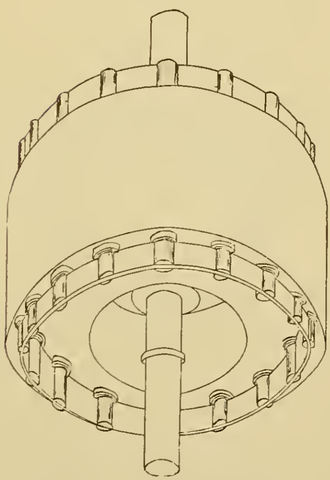


FIG. 15.

current motor and the secondary winding to the *armature* of the direct-current motor.

The induction motor is built to operate on either the ordinary alternating current shown in Fig. 5 or on currents of two or more

phases. This form of motor attained its first practical development in this country at the hands of Tesla, who found, after much experimenting, that commercial results could be secured in such a motor if currents of two or more phases were used to produce a so-called rotating magnetic field. He found that he could produce this rotating magnetic field by having on his motor two or more entirely independent field windings. By giving these windings the same relative position in the motor as the different phases of his

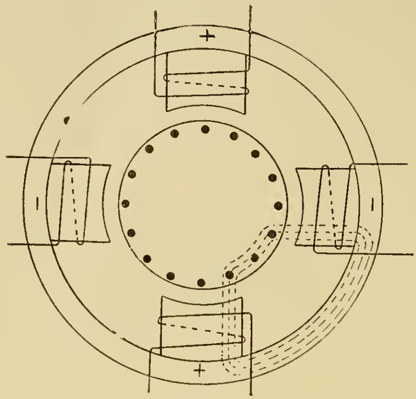


Fig. 16.

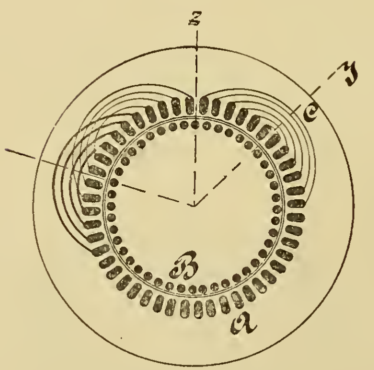


Fig. 17.

supply current bore to each other, he found that he could produce the effect of a strong magnetic pole revolving around the surface of his armature at a speed, in revolutions per minute, depending upon the frequency of alternations of his current. In a motor such as that shown in Fig. 14, for example, he wound what would ordinarily be a 12-pole machine in such a manner as to give him three sets of 4 poles each (thus producing a 4-pole machine), into

which he could introduce three phases of current supply. One phase, supplying a set of poles AAAA, produced poles the strength of which followed a periodic wave just as did the alternating supply. At any one instant such a pole might be positive. As its strength began to decrease a second phase of current, supplying a set of poles BBBB, caused a gradually increasing strength of pole which had the effect of shifting the pole from A to B, and so on. For such a field winding it was, in course of time, found advantageous to use a form of armature illustrated in Fig. 15. In this armature the winding of copper conductors consists simply of a large number of bars completely short-circuited at both ends, with respect to each other, by a copper ring. The resemblance of this

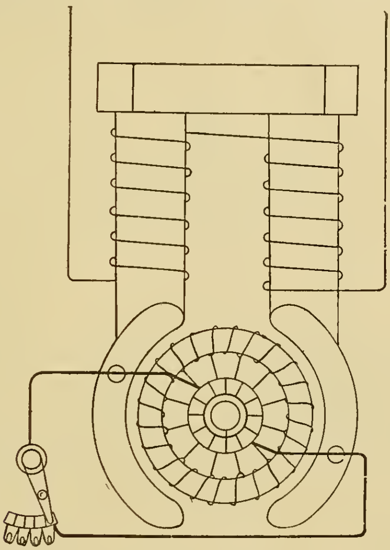


Fig. 18.

form of winding to an old-style squirrel-cage gave rise to the popular name of a squirrel-cage winding. Such an armature placed in a rotating magnetic field will start from rest with a large torque, and will quickly run up to a speed slightly less than the number of alternations of the current supply divided by the number of poles of the winding. In other words, if the motor in Fig. 14 were supplied with alternating currents of 7200 alternations per minute the speed of rotation of the armature would be slightly less than 1800 revolutions per minute, there being four poles of the winding.

Such a motor supplied with single-phase currents, as for example Fig. 16, however, will not start from rest. This is due to the following reasons:

The currents generated by induction in the armature conductors when the armature is standing still select such paths of flow as to produce no turning couple. Some of the currents tend to produce rotation in one direction, while others tend to produce rotation in another. They thus nullify each other in so far as turning moment goes. In the two-phase and three-phase motors, however, a different condition exists. The currents produced in the armature by any one set of poles bear the right relation to the poles of the next phase to afford an effective turning couple, and therefore the multiphase motors are very effective in starting from rest. Accordingly it is not surprising that very soon after the discovery of the induction motor and a reduction to practice of the principles of generating and transmitting two-phase and three-

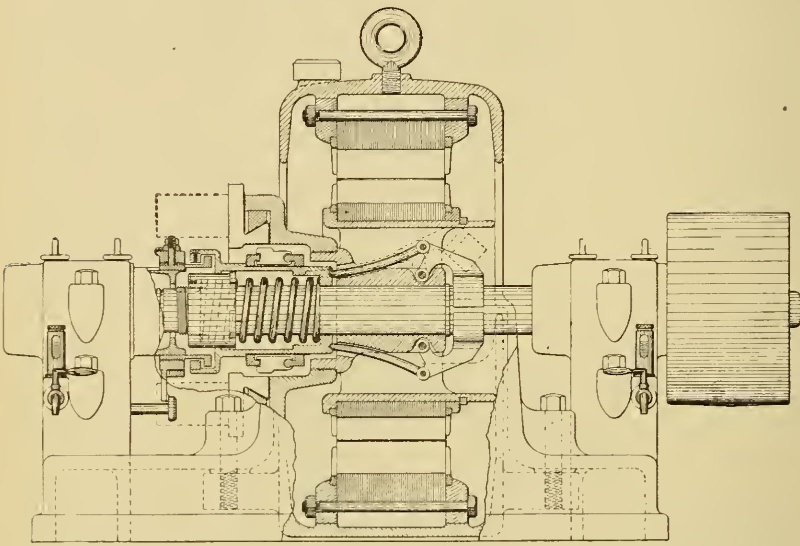


Fig. 19.

phase currents excellent two-phase and three-phase power motors were placed upon the market. Those manufacturing companies owning the two-phase and three-phase patents were not slow to develop a complete system of two- and three-phase power transmission, utilizing induction motors satisfactory to a very high degree.

Great inducement existed, however, to produce a satisfactory single-phase motor operating along the same general lines. First of all, a very large percentage of the alternating-current central

stations in existence made it necessary, if these plants were to supply alternating-current power motor service, either to develop single-phase alternating-current power motors or to discard their old generating apparatus. Further than this, if good single-phase motors could be produced which would not introduce disturbing

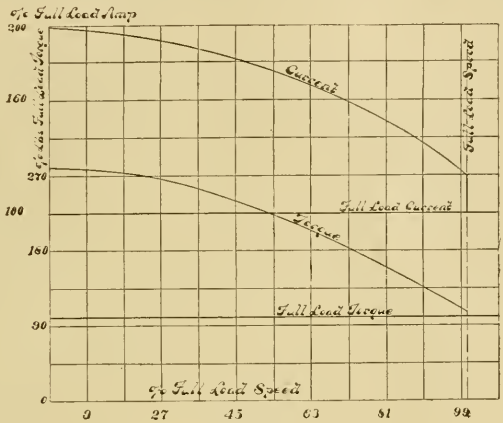


FIG. 20.

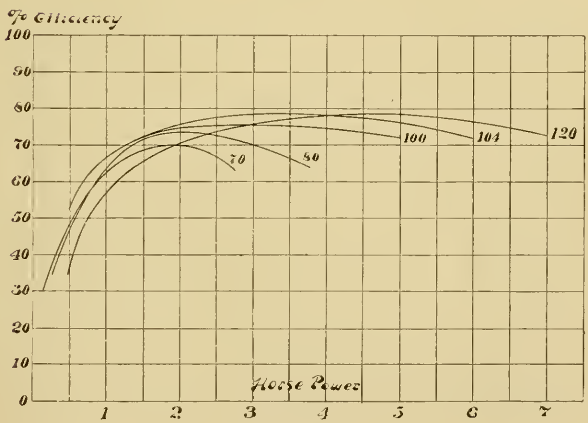


FIG. 21.

effects, in so far as lighting service was concerned, a single-phase system would possess very material advantages over the two-phase or three-phase system.

Therefore the aim of many investigators has been, even since the advent of the successful two- and three-phase motors, to develop and offer to power users generally a thoroughly practical

and commercial single-phase power motor. Such a motor has been brought out by the Wagner Electric Manufacturing Company, of St. Louis, and it is of this motor that I desire to speak in detail. The mechanical construction of the motor is in many respects like that of the two- and three-phase motors on the market. A field is built up of iron plates very much like A of Fig. 17, and an

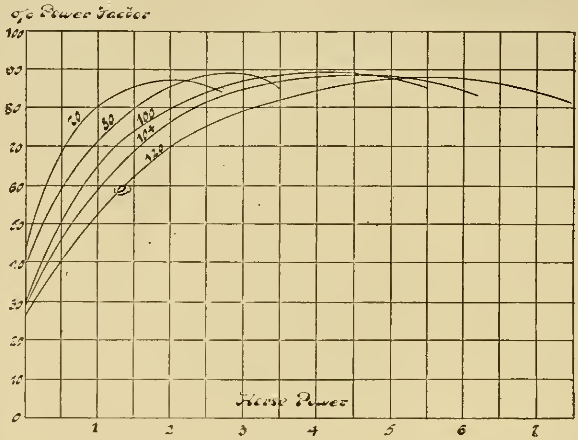


FIG. 22.

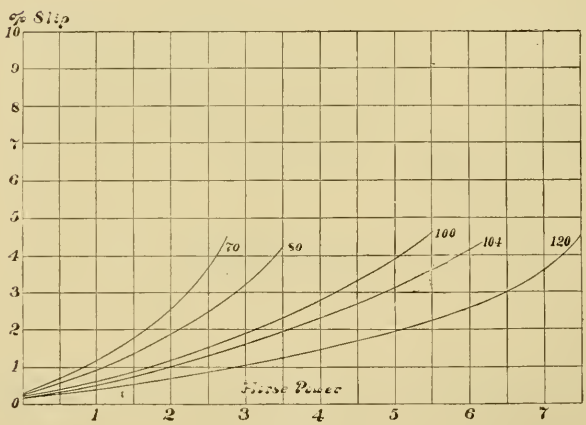


FIG. 23.

armature core is also built up from iron plates very much like B of Fig. 17. The field is wound with coils threading through the slots of the punchings, as shown at C, Fig. 17, so as to produce a magnetic pole of intensity varying from a maximum along the radius XY to zero along the radius XZ. For motors of 60 cycles and in smaller sizes it is customary to make these field windings 4-pole.

The armature cores are wound with an ordinary direct-current progressive winding, connected up to a commutator in exactly the same fashion as in the direct-current motor winding. The commutator of this armature is so designed that it may be completely short-circuited by introducing a short-circuiting circle of copper segments. When so short-circuited this winding affords a substitute for the squirrel-cage form of winding, differing from the squirrel-cage in

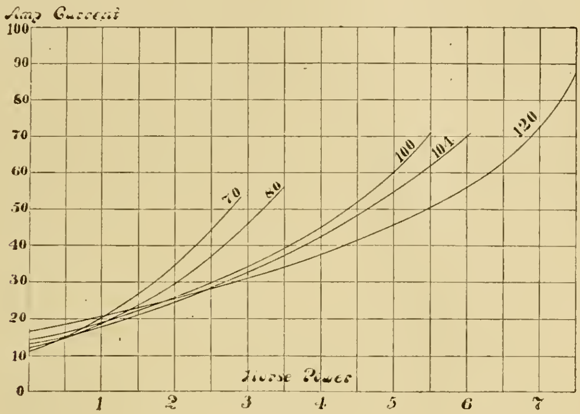


FIG. 24.

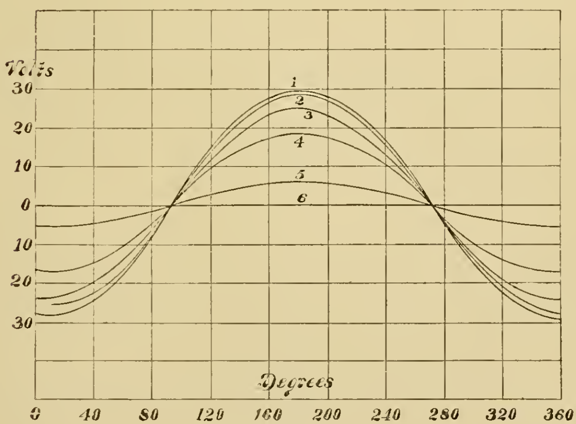


FIG. 25.

that, instead of the currents being left to select paths for themselves, they are restricted to flowing in paths afforded by the individual coils of the armature winding. The operation of this motor is based wholly upon the principle that an induction motor with a completely short-circuited armature will, when up to the running speed, operate on single-phase current supply in exactly the same manner as it operates in a two- or three-phase motor with two-

and three-phase current supply. In other words, the disadvantage of the single-phase motor, as compared with the two- and three-phase motors, disappears when up to running speed. Therefore, in developing a successful single-phase motor, the problem to be met was the provision of a starting device which would afford ample starting torque at all speeds between rest and running speed

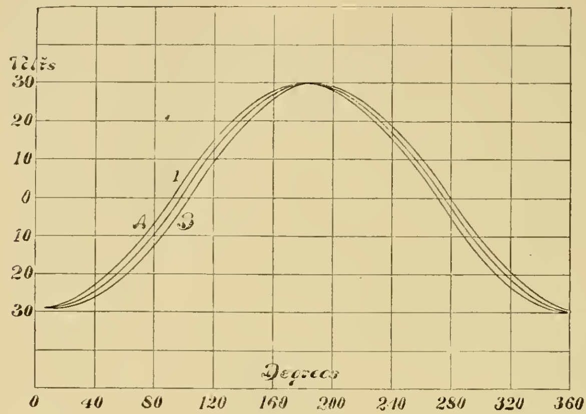


FIG. 26.

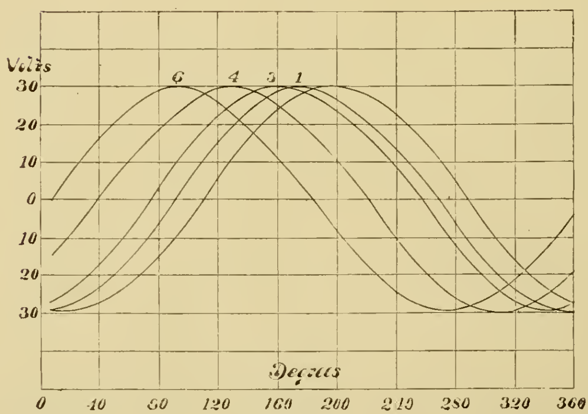


FIG. 27.

without excessive consumption of current, and of a mechanical construction equally durable with the rest of the motor. In doing this the Wagner Company has developed to a high degree of mechanical and electrical perfection a type of motor equal in all respects, and superior in several, to the best forms of the direct-current motor. In effect, this motor starts with the same characteristics of torque and current consumption as does the ordinary series-wound direct-

current motor, such as is found in all street car equipments, for example. The armature winding is short-circuited through carbon brushes bearing upon the commutator surface. The field generates, by induction, currents in the armature winding, which currents flow out through the carbon brushes either into an outside resistance or, where a direct short circuit of the brushes is provided, out through one brush and back into the armature through the other. By the shifting of the brushes on the commutator surface these armature currents are forced to take such positions, relative to the magnetic poles produced by the field, that a repellent action between these armature currents and the poles of the fields is effected and rotation results. In other words, the currents which would be ineffective in an armature construction such as was shown in Fig. 15 are forced to take such positions that they become equally effective with

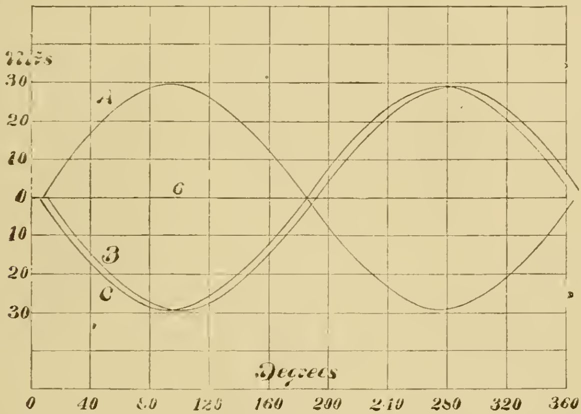


FIG. 28.

the currents produced in the armatures of two- and three-phase motors. This arrangement of affairs, illustrated in Fig. 18, is employed in bringing the motor up to running speed. When running speed is attained the brushes are no longer required, and the armature winding is completely short-circuited, after which the armature runs purely as does the armature of a two- and three-phase motor.

In the mechanical development of this form of motor many novel features have been introduced. The commutator is of the radial, instead of the horizontal, type. The short-circuiting band is made up of small copper links, which links, being in turn mounted upon a short-circuiting ring, are thrown into the annular opening in the commutator, and by making close contact with each segment produce a very effective short-circuiting of the entire armature

winding. In the operation of the motor it is very advantageous to have this short-circuiting accomplished either at the running speed or very slightly below. To remove all uncertainty on this score, the Wagner Company's motors are built with an automatic device for performing this operation. This device consists of a set of governor weights acting against a spiral spring. The centrifugal action of the weights will, at the proper speed, force the short-circuiting links into the commutator against the action of the spring. At the same instant, and by the same means, the brushes bearing upon the commutator are thrown off, and therefore, in the running condition, the motor runs with much less noise than does the direct-current motor. (See Fig. 9.) These motors are so designed as to carry a large percentage of overload without serious consequence. If this capacity for overload is exceeded this type of motor will

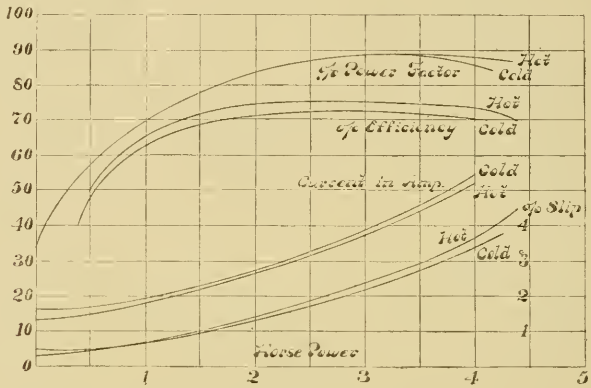


FIG. 29.

come to rest in exactly the same way as will a two- or three-phase motor under the same conditions. If the overload is temporary the motor will, without any further attention, run back up to speed, as in slowing down the brushes are thrown back on the surface of the commutator by the automatic device, and the motor is again placed in the starting condition.

In its electrical design this motor has been as highly developed as in its mechanical features, and the builders claim for it results practically identical with the best that have been secured with the two- and three-phase motors. The important characteristics of such a motor are its starting torque, consumption of current in starting, consumption of current while running idle without load, power factor, efficiency and slip. The starting current of this motor can be varied at will to meet all requirements of the service. This is accomplished by shifting the brushes upon the commutator

surface. If large starting torque is essential, the proper placing of the brushes will produce this, the current consumption bearing practically a direct ratio to the amount of torque. If a very small torque only is essential, the starting current can be reduced to a very small amount. The motors, when they leave the factory, are so adjusted as to provide sufficient torque to bring up their full load. The relation of starting torque to starting current is shown in Fig. 20. The energy required to operate the motor without load is very small, being practically the same as that required by direct-current motors. The efficiencies which have been secured in these motors are practically identical with those secured in the best direct-current motors. The power factors are as high as those secured

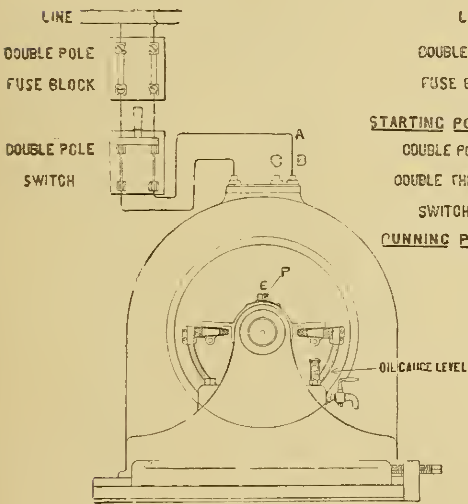


FIG. 30.

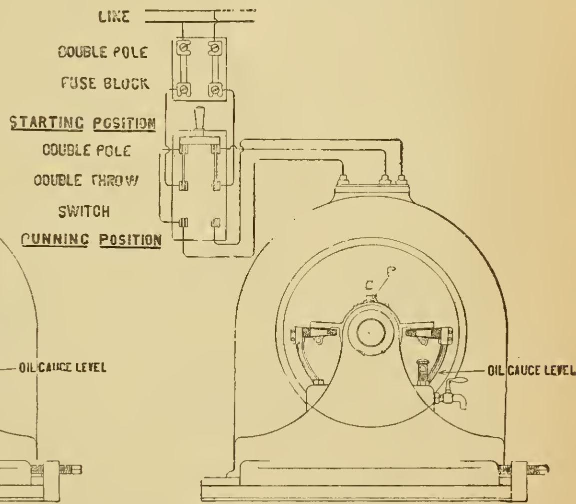


FIG. 31.

in two- and three-phase motors, and the slip is very small indeed. By this latter factor of slip is meant the decrease in speed between no load and full load. It may be said that this is about the same as in a good shunt-wound direct-current motor. In Figs. 21 to 28 I have shown the results of a test made by students of the University of Nebraska, during the spring of 1898, upon a 5-horse power motor. These tests were made under the direct supervision of Professor R. B. Owens. One set of tests was the measurement of the various electrical factors with different applied electrical pressures at the terminals of the motor. In other words, the motor, as sent out by the builders, was designed to operate on a pressure of 104 volts and on 60 cycles. Tests were made with a variation of this voltage in steps between 70 and 120. The effect of these

various voltages upon the several factors are very nicely illustrated in Figs. 21 to 24, inclusive. The judiciousness of the ratings given by the builders is, I think, very clearly brought out in these curves. A particularly noticeable feature is the small percentage of slip at the rated capacity of the motor,—namely, 3 per cent.

Another set of tests was made by these gentlemen for the determination of the exact magnetic actions going on in the motor. In other words, they attempted to determine, under all conditions of load, as well as when standing idle, the exact form of magnetic field produced by their single-phase sign-wave current supply. To determine these measurements they introduced exploring coils in the slots of the field punchings. Each of these exploring coils embraced

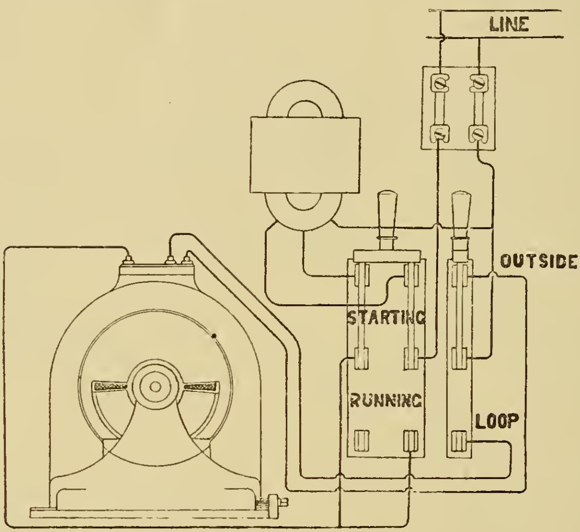


Fig. 32.

one-fourth of the slots of the entire field punching, corresponding in that way to the exact breadth of the polar winding of the motor. These exploring coils were introduced progressively around the frame in such a way that the first one enclosed the entire winding of one pole, the next one eight-ninths of the winding of one pole and one-ninth of the winding of the next pole; the third one enclosed seven-ninths of the winding of one pole, and two-ninths the winding of the next, etc., progressively, until a point was reached where half of one pole and half of the next pole were enclosed. By the proper introduction of measuring apparatus the experimentors could accurately determine at any one instant the magnetic strength in the section of the field embraced by each coil.

Therefore, plotting these instantaneous results with respect to time, they could determine the exact form of a wave and its net numerical value all around the interior surface of the field punchings. In Fig. 25 the results of their tests are shown with the motor standing still. The result here is just what might have been expected,—namely, that in this condition of affairs the field is a pulsating one, and decreases in magnitude at any instant as we progress around the circumference of the field from the central radius of each pole. In Fig. 26 is shown the reactive effect of the armature upon the strength of the field immediately in the center of each pole-winding between the limits of no load, half load and full load in one direction. The displacement seems to correspond in percentage to the percentage of slip. In Fig. 27 are plotted the reactive results on the magnetic field, caused by the rotation and the current of the armature winding. A close study of these curves, as compared with the curves of Fig. 25, reveals the fact that the armature reactions of the motor when up to speed are such as to change entirely the character of the magnetic field, actually producing as perfect a rotating magnetic field as is created by a multiphase current supply. In Fig. 28 is shown the reactive effect of the armature upon that portion of the field embraced in the exploring coil, which gives a horizontal line in Fig. 25. Here Curve 1 shows that the resultant magnetism enclosed by this exploring coil is zero when the motor is at rest. Curve 2 shows the condition of affairs with the motor running in one direction. Curve 4 gives the corresponding result with the motor running in the other direction. Curve 3 shows the displacement of 4, due to load of the motor. These various magnetic curves are worthy of much closer study than can be given them within the limits of this paper.

Another test made by the university students was to determine the effect of continuous load upon the motor; in other words, to compare the electrical conditions of the motor operating cold and hot. These results are shown in Fig. 29, and disclose the fact that the motor is more efficient and operates with better results in every respect, except slight increase in the percentage of slip, when hot than when cold. In the winding of these motors it is possible for the builders to secure a variety of results. In other words, where a very large starting torque is required an auxiliary connection can be made, the effect of which is to rate up the motor in capacity. The builders term this a loop connection, and for this connection they provide a third terminal upon the terminal board. If the circuit is connected to this terminal and the common terminal for starting, 50 per cent., 75 per cent. and in extreme cases 100 per

cent. overload may be brought up to running speed. When up to running speed connections are changed by means of a throw over switch in the supply circuit, so that the current is supplied to the normal winding of the field. The diagram for connections in such circumstances is shown in Fig. 30. Where the starting torque required is normal, the diagram for connections is as shown in Fig. 31. If it is desired to limit the starting current for the purpose of avoiding line drop of pressure, the builders furnish a small transformer for reducing the pressure applied to the motor terminals. The connections under such circumstances are as shown in Fig. 32, and the result accomplished is the cutting off of that part of the torque and current curves of Fig. 20 above the 150 per cent. line. The extreme simplicity of the motor arises from the fact that it can be connected upon the same circuit with incandescent lamps, and that it operates without any disadvantageous effects on incandescent circuits. Furthermore, operating on a low tension, there is no danger from accidental contact. If it is desired, however, to operate on higher voltages, windings will be provided to correspond. The manufacturers have designed alternating-current motors of this character up to and including 20 horse power capacity for 60 cycles, and 15 horse power for 133 cycles. It is understood that larger sizes are to be brought out in the near future. It may be said in passing, however, that practically the limit of requirement for ordinary commercial power purposes is 50 horse power capacity. The limit of adaptability of this motor to various descriptions of power work is set by the necessary frequency of starting, as above explained. The motor cannot be continuously operated upon the commutator, and so long as the starting is of infrequent character satisfactory results can be guaranteed. For ordinary running service, where starting but a few times a day is necessary, the life of the commutator is indefinite, and motors are running in the shops of the Wagner Company, which have been in service for two years or more, the commutators of which have never received more than a very limited amount of attention.

PATENTS AND MONOPOLY.

By John Richards, Member Technical Society of the Pacific Coast.

[Read before the Society, November 3, 1899.*]

Before entering upon the main part of the subject to be presented, and in order to define the limits of the paper, I will explain that there is no intention to sustain or to condemn the policy of granting patents for inventions. The equities and conditions that surround this phase of the subject, such as that occult faculty recognized in law, the inventive faculty, and the inherent rights arising therefrom, would lead into long and profitless discussion.

Twenty-eight years ago I wrote a pamphlet, much more extensive than the present paper, to contend that inventions in the useful arts should not become the property of individuals when such inventions or discoveries were deducible from common premises, the results of science and acquired skill, and that priority in inventions consisted generally in the discovery of wants.

Such speculations, interesting as they may be to follow out, are of no practical value in the face of the fact that nearly all civilized countries, Holland excepted, have patent laws or systems of granting an exclusive use of new inventions. It is not, therefore, a theory we have to consider, but a condition.

While the system of granting patents for inventions has remained measurably the same for a quarter of a century past, the industrial interests affected thereby have been greatly changed and centralized, establishing, or tending to establish, a new relation of personal rights in invention. This is the principal theme of the present paper, and is in every way, I think, a suitable subject to be brought before this Society, which alone on this coast is in position to discuss a problem of so technical a nature as the relations between inventions and industry, and in how far the best relation can be established by the patent laws and the methods of procedure in the bureau.

In the American *Review of Reviews* for June, 1899, in the editorial notes, under the head of "The Rights of Monopoly," there appeared the following remark:

> The Government Patent Office every day grants control over certain inventions with the avowed object of promoting for a term of years a strict monopoly. If, in some field of industry not dependent upon the protec-

*Manuscript received November 15, 1899.—Secretary, Ass'n of Eng. Socs.

tion of the patent laws, a monopoly should arise by reason of the fact that a single individual or firm or corporation had come into control of the entire production of a given article, it would not follow necessarily that there was any greater propriety in this particular monopoly than in those especially fostered by the Government under its patent laws.

It is a curious conception that places patents for inventions in the category of monopolies. There is scarcely even analogy between a patent and what is commonly understood by monopoly. The inventor must, before he enters upon an exclusive use of his own discovery, prepare it for public use at the end of a term of years, averaging fifteen, by means of carefully executed specifications and drawings, which, if faulty, incomplete or insufficient to disclose fully his invention, invalidate his right of exclusive use. This does not appear like monopoly.

In its nature a patent is simply a compact between an inventor and the public, whereby he is for a limited time permitted on certain conditions to use exclusively what is already his own by natural right, on condition of disclosure and dedication to public use at the end of a term scarcely long enough to develop his invention; he paying all the fees for registry and conveyance to the public and something more than this, because at this time in this country inventors have overpaid such expenses to the extent of nearly four millions of dollars, now lying in the National Treasury.

In the case of authors and their writings the terms are more liberal. The period of personal right is longer, is renewable and is more carefully protected by law. The fees of registry are merely nominal, and encouragement is in every way extended, as it no doubt should be, on grounds of expediency as well as of equity and right.

The history of patents for inventions fully discloses their nature. The various patent systems of the world may all be said to rest upon a modification of an old English law called the Statute of Monopolies, which, previous to 1633, had led to various abuses by special grants or privileges, called "patents," that were sold or bestowed by the crown upon favorites. Such grants, then considered "acts of grace," were given for an exclusive right to make or sell special commodities, even the common necessaries of life, such as salt, which was once the subject of a patent. This was monopoly.

The abuses under this law, the Statute of Monopolies, became so intolerable that it was repealed in 1633, except in so far as inventions were concerned, and was in effect superseded by the present statute, which confines personal monopoly to "inventions," or what was "new in the realm," so that no citizen should be abridged in any right he had previously enjoyed. Section 6, on which the patent laws rest, reads as follows:

> Provided that any declaration before mentioned* shall not extend to any letters patent and grants of privilege for the term of fourteen years or under hereafter to be made of the sole working or making of any manner of new manufactures within this realm to the true and first inventor of such manufactures, which others at the time of making such letters patent and grants shall not use, so as also they be not contrary to the law nor mischievous to the State, by raising prices of commodities at home, or hurt of trade, or generally inconvenient, the said fourteen years to be accounted from the date of the first letters patent or grants of such privilege hereafter to be made, but that the same shall be of such force as they should be if this act had never been made, and of none other.

As before remarked, this old law has stood for 266 years as the foundation on which patent laws are founded in all countries where such rights are conveyed to inventors. It was obvious to Parliament that no monopoly could exist in respect to inventions, and these were accordingly excluded in the repeal of the old law.

Sir Edward Coke, the great English jurist, defining the scope of the revised statute, said:

> An illegal monopoly is a grant or allowance from the king by his grant, commission or otherwise to any person or persons, bodies politic or corporate, of or for the sole bringing in, selling, making, working or using anything whereby any person or persons, bodies politic or corporate are sought to be restrained of any freedom or liberty that they had before, or hindered in their lawful trade.

Numerous authorities could be given showing that not only are patent grants for invention free from the feature commonly understood as monopoly, and are no restraint upon the rights of the commonwealth or of persons, but also that, notwithstanding these clear facts of history, the old original concept of a monopoly patent has lingered for more than two centuries, as is seen in the quotation given at the beginning of this article and in others to be hereafter noted. As a matter of fact, patents for inventions, since 1633, instead of constituting a monopoly, have been a limitation of a natural right that inheres in the person, the equity of such limitation resting on an assumed probability that within a certain period of time the public would by other means become possessed of the same discovery.

Nothing is confirmed by a patent grant. It is simply a warrant of privilege to appeal to the courts for the protection of a personally created new property, and even this right, as before pointed out, is made conditional on the fact of an originality which the inventor must himself, at his own expense, establish, in most cases against prejudice and nice discriminations of a technical nature scarcely definable in set laws.

---

*Referring to the act repealing the Law of Monopolies.

The patent laws of the United States were instituted 160 years later than those of England, and, while differing in many provisions from the British system, recognize fully the principle, laid down in the repeal of the Statute of Monopolies, that no grant should bar from use or enjoyment any knowledge or right held by any one before the discovery or invention patented.

One distinction from the British system is in the meaning attached to the name "inventor."

In the quotation from Chief Justice Coke it will be noticed that he includes, with discovery, "sole bringing in." This yet constitutes "invention" in Great Britain and some other countries. In fact, the term, etymologically considered, means to "bring in," being derived from the Latin *in* and *venire,* to come in, or bring in, and applies especially to the introducer of an invention or to "communications from abroad"; but there are provided reasonable safeguards to prevent abuse of this privilege.

In the United States the limitations are more strictly drawn. Inventions are made purely personal, without power of delegation from a living inventor. He alone can procure a patent, and should error be made by false or mistaken statement, so as to abridge the rights of an earlier inventor, the statute provides means of correcting such mistake and confirming the grant to the actual first inventor, thus carefully protecting not only the public but each individual against the infraction of any privilege previously enjoyed.

The Constitution of the United States confers upon Congress the power to grant, for a limited time, to authors and inventors, an exclusive right to their writings and discoveries for the promotion of science and the useful arts. This took form at the end of the last century by the enactment of a patent law which in 1870 was revised and put upon a more permanent basis, which has lasted without material change to the present time, and which, with an exception to be hereafter mentioned, has operated in a satisfactory manner.

This law, under the circumstances of our time, furnishes almost the sole means whereby a small industry can be started and carried on, notwithstanding that for fifty years or more patented inventions were a common basis for extensive industrial organizations.

In manufactures so founded individual skill was the prominent and often the main factor. Men without capital were able to acquire and control interests in various industrial enterprises, especially such as grew out of small individual beginnings founded on patents for inventions. Now circumstances have changed. In

the enormous activities of modern industrial development individuality is practically eliminated, and various means of monopoly have arisen.

Such means consist in the control of legal and other employed skill; the purchase of material and supplies at a reduced rate; reduction in the cost of transportation; borrowing money at low rates of interest; reducing the expenses of management; saving in the expenses of advertising; raising the price of the product, with many other advantageous conditions which go to make up monopoly and occupy the former place of patented inventions.

In this manner there has arisen a conflict of interests and a jealousy of patented inventions that will no doubt in the near future lead to attempts at modifying the patent laws, or to a new construction of them by the courts that will impair the rights of inventors. Even at this time we have a decision in which by an unparalleled dictum a Federal judge has set aside an important and generally recognized patent* by deciding a *want of invention.* Such an assumption was contradicted by facts, testimony and the opinions of those skilled in the art. If one patent can be destroyed in this manner, why may not any other meet the same fate The judge of a court may from facts decide questions of infringement and of novelty, because these rest upon fact, and skilled aid can be called in to clear up history and technical features; but when a court assumes to determine the *degree of invention* in a case, this leads into a field that has no limit and to the exercise of functions that belong to the skilled officers of the Patent Office. An officer of the law, not skilled in the arts, is not competent to set up a measure of invention.

The whole world seems engaged in a wild race for gain. The commercial incentive becomes stronger each year, and the frantic attempts to adapt laws to the new circumstances show the slow and unwieldy nature of legislation and the difficulty of framing "rules of action" for new arts and interests. In one decade, or even in half that time, may arise discoveries and economic changes that greatly affect the social relations of people; and this rapid and revolutionary march of centralization and the altered social conditions produced thereby are the primal causes of unrest and the many turbulent social problems that are at this time forcing themselves on the attention of thinking people.

The effect of an attack upon the patent system, and the results that would follow in the social, economic and industrial interests of

---

*U. S. Circuit Court, District of Northern California, Johnson *vs.* Woodbury, No. 11,934, 1899.

the country, are matters of serious import. Even now a small manufacture of any commodity of common use is impossible unless the product or process is protected by a patent. Hence the incentive to disparage and impair such protection by classing it with "monopoly."

There are now enrolled in Congress no less than seventy bills that would, if enacted, affect the patent laws or procedure. Some of these bills are for useful purposes, and more of them are not. Some of them have their initiative in personal objects, and many indicate a want of information respecting the nature and equities involved in patent grants.

There is no sufficient understanding of patent matters in Congress any more than there is among the people; besides, there is the impediment to the consideration of such bills that they are of a national character, and lack the usual incentives to promote their consideration. So the subject is neglected, while the Patent Office, with an enormous surplus fund lying in the National Treasury, is without even the required room and facilities for transacting its business.

Fortunately, however, an association of leading members of the bar and patent attorneys at Washington, many of whom have held executive positions in the bureau, give consideration to new bills affecting patent laws and procedure. The *Patent Law Association* considers the various proposed changes, publishes digests of new bills and may be said to control legislation to the extent of preventing the enactment of new laws and rules that would lead to bad results. It also promotes what tends to improvement of the system.

To illustrate the methods of this organization, the *Patent Law Association* in November, 1898, published a bulletin containing a digest and review of pending Congressional bills, and, in respect to two affecting the trade-mark law (H. R. No. 2807 and H. R. No. 3128), has this to say:

> Of the many lawyers to whom these bills were presented for criticism not one indorsed any of them. The singular lack of precision, joined with the comprehensive scheme of the undertaking and the insistence with which they were urged, makes these bills peculiar examples of what must be met by all associations and individuals who have at heart the real advantage of the law and the good of all.

Two characteristics of the American Patent Bureau are noteworthy,—the purity of its administration and its paternalism.

Throughout the century of its existence there has never arisen any serious case where the integrity and good faith of the officers

have been called in question. They are in a great measure free from the baneful influences of political preference, and have maintained a spirit of independent action strange to find among so much of an opposite character. The popular confidence thus gained has rendered possible the present "paternal" features of procedure.

By paternalism is meant the elaborate system of examination performed by subordinate officers clothed with the power of witness, counsel and judge. A "triple function" it may be called. Each primary examiner exercises all of the functions of the bureau up to appeal; adducing testimony as to the novelty of inventions, the relation and bearing of such testimony and then *passes judicially upon his own findings.* This work, if advisory, or if it resulted in "objection," would be as logical as it is useful, but it is not consistent with the fact that there is no corresponding power to "confirm." It is a proceeding that acts in one way only.

An applicant has to assume the whole responsibility when his application is "allowed." Infraction of his patent gives him the privilege of complaint in the courts, but nothing more. If his case is rejected he has no standing or privilege, no matter what the real facts may be.

During procedure he is put in the position of a humble petitioner praying for the allowance of his claims, asking for all he can get and taking what in the examiner's opinion he should have. This constitutes a paternal system, and is responsible for the widely prevalent opinion that an "allowance" of a patent is at the same time a confirmation of its validity.

This paternal system gives rise to the existence of incompetent attorneys and to faulty methods of procedure, because both inventors and their agents depend on the office and commonly present their cases in an imperfect or overdrawn form, based on the rule, "Claim everything, and get what you can." Out of this form of procedure arises the common opinion that a patent is an "act of grace,"—a favor and privilege emanating in and conveyed by the Government.

This conception of patents for inventions furnishes logical grounds for the charge of monopoly. It also presents a vulnerable point of attack by those whose interest it is to destroy property in invention. This mode of procedure is not necessary, as is proved by the fact that repeated and invalid patents are as common in this country as those where the applicant and his attorney assume the responsibility of novelty and the governments deal only with form.

Competent attorneys who prepare here applications for patents in foreign countries will understand this peculiar method of pro-

cedure in domestic cases, and are governed accordingly. For the American office they will draw a large number of ambiguous claims, approaching the novel features of the invention from various sides, introduce technical language not capable of being understood in a popular way and in amendments proceed to hair-splitting distinctions.

Specifications for other countries are drawn with the essential features of the invention expressed usually in a single claim and in plain terms, describing the thing or part invented as nearly as the applicant and his attorney can determine this point, and usually in a way to secure a sound patent when there are grounds to admit of such.

It is not contended that the methods of procedure in this country can at once be altered. We have drifted into a system that permits almost any one to become a patent attorney, depending on the bureau to do the work. To change this and to make the applicant responsible in procedure, as he is in fact, would eliminate the paternal feature and at the same time remove a false conception of the nature of a patent.

Referring further to the relation between patents and monopoly, in September of the present year there assembled at Chicago a congress of men, eminent in economic matters, to deliberate on "trusts" or the monopoly exercised by these combinations. One of the delegates to this conference, Professor Jenks, read a paper before that body in which, with other suggested inquiries or problems, was one as to "whether the patent laws should not be so changed as to prevent the right of monopoly accruing to the patentee," thus placing inventions in the same category with commercial monopolies.

Mr. Bourke Cockran, of New York, in an address before the same body, said: "Now, there are three ways in which the Government interferes in the trade of the individual in this country; one is by patent laws."

He names patents first as a cheap kind of monopoly, and then goes on to recommend the suppression of monopoly by the remedy of "publicity."

How would it do, let one ask in amazement at this statement, to issue charters in the same manner as patents on inventions? For example, (1) the term to last seventeen years; (2) the applicant to file at the beginning a complete exposition of his business for public use at the end of this term; (3) to make the privilege contingent on there being no interference with rights previously enjoyed by others; (4) to declare in a publicly printed document the nature,

conditions and limitations of the grant and sell the same for five cents a copy.

This, it seems, should satisfy Mr. Cockran's desire. What he has in mind is, no doubt, to throw around all kinds of chartered privileges some such restrictions as are now applied to patents for inventions. If that were done the monopoly would be eliminated, as it is by the spirit, letter and intent of patent laws as they have existed since 1633.

Since the foregoing matter was prepared the Assistant Commissioner of Patents in this country, Mr. A. P. Greeley, has published a volume entitled "Foreign Patent and Trade-Mark Laws." In this volume are various explanations and comments on the differences in systems and procedure. On pages 18 and 19 the following will be found:

The idea that the grant of a patent for a new invention is in some way in derogation of the rights of others, and that it is for the interest of the public that the invention should be made free to any one to use at as early a date as possible, is not yet wholly overcome, even in the United States. * * * In the United States, while a patent once granted is not liable to forfeiture for any cause, the disposition to consider that the public interest demands that every technicality of the law should be taken advantage of against the patentee, particularly in the construction placed on the claims of his patent, has, it is to be feared, too often resulted in depriving a meritorious inventor of the protection to which he was justly entitled.

On pages 32 and 33 the following will be found:

The countries which can be said to have patent offices properly equipped to make anything like an exhaustive examination on the question of novelty are, besides the United States, Austria, Canada, Denmark, Germany, Japan, Norway, Russia, Sweden and Switzerland. In all of these except Switzerland a patent is refused if the invention is found to be not patentably new. Under the Swiss law, the applicant is informed of the result of the examination and given an opportunity to amend, if necessary; but if he does not do so, or insists that a patent issue, even though the invention is shown to be old, the patent cannot be refused. A similar plan is under consideration in Great Britain, and is likely to be adopted.

On page 37 the following, including a footnote, appears:

And while patents granted after preliminary examinations are very often submitted to experts for opinion as to their validity, especially if suit for infringement is to be brought on them, they are recognized, generally, as *prima facie* valid.

While this is true of all other countries in which the preliminary examination system prevails, and was true of the United States up to 1879, it cannot, unfortunately, be said to be strictly true at present of the United States.


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MEXICO.
GULF OF MEXICO
ATLANTIC OCEAN
PACIFIC O.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
ST. LOUIS
CINCINNATI
LOUISIANA
PACIFIC COAST
WASH.
ORE.
IDAHO
MONT.
WYO.
N. DAK.
S. DAK.
MINN.
WIS.
MICH.
IOWA
NEBR.
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
KY.
W.VA.
VA.
MD.
DEL.
MASS.
CT.
ME.
N.C.
S.C.
TENN.
ARK.
OKLA.
IND. TY.
ARIZ.
N. MEX.
TEX.
LA.
MISS.
ALA.
GA.
FLA.
120
105
90
75
45
40
35
30

Editors reprinting articles from this journal are requested to credit both the Journal and the Society before which such articles were read.

Association of Engineering Societies.

Organized 1881.

Vol. XXIII. December, 1899. No. 6.

This Association is not responsible for the subject-matter contributed by any Society or for the statements or opinions of members of the Societies.

THE INFLUENCE OF MECHANICAL DRAFT UPON THE ULTIMATE EFFICIENCY OF STEAM BOILERS.

By Walter B. Snow, M.E.

[Read before the Boston Society of Civil Engineers, October 18, 1899.*]

A discussion of the influence of mechanical draft upon the ultimate efficiency of steam boilers may very properly be introduced by a word regarding the apparatus, and a brief description of the methods employed in its production. In its generally accepted form the apparatus consists of a fan blower inclosed in a case and provided with the necessary means for its operation.

The fan wheel itself consists of a number of radial blades carried upon T steel arms cast into the hub. Side plates bind the blades together, and provide two inlets concentric with the shaft; one upon each side of the wheel. The air enters through these inlets and is by the action of centrifugal force delivered tangentially at the tips of the blades, which conform to the outer circumference of the wheel. The air, thus discharged, is, by means of a surrounding case, conducted to an outlet in its circumference.

The volume delivered by a fan is proportional to its speed, while the pressure created varies as the square of the speed, and the power required as the cube of the speed.

Mechanical draft may be applied under either of two general methods, the plenum and the vacuum. Which is to be employed must depend upon the circumstances, for it cannot be asserted that either is unqualifiedly superior under all conditions. As ordinarily applied, under the plenum or forced draft method, the air is forced into the closed ashpit under pressure, and thence finds its escape through the fuel on the grates above. Its success depends largely upon the manner of introduction of the air to the ashpits. For

*Manuscript received November 23, 1899.—Secretary, Ass'n of Eng. Socs.

this purpose a special form of damper is desirable, as shown in Figs. 1 and 2.

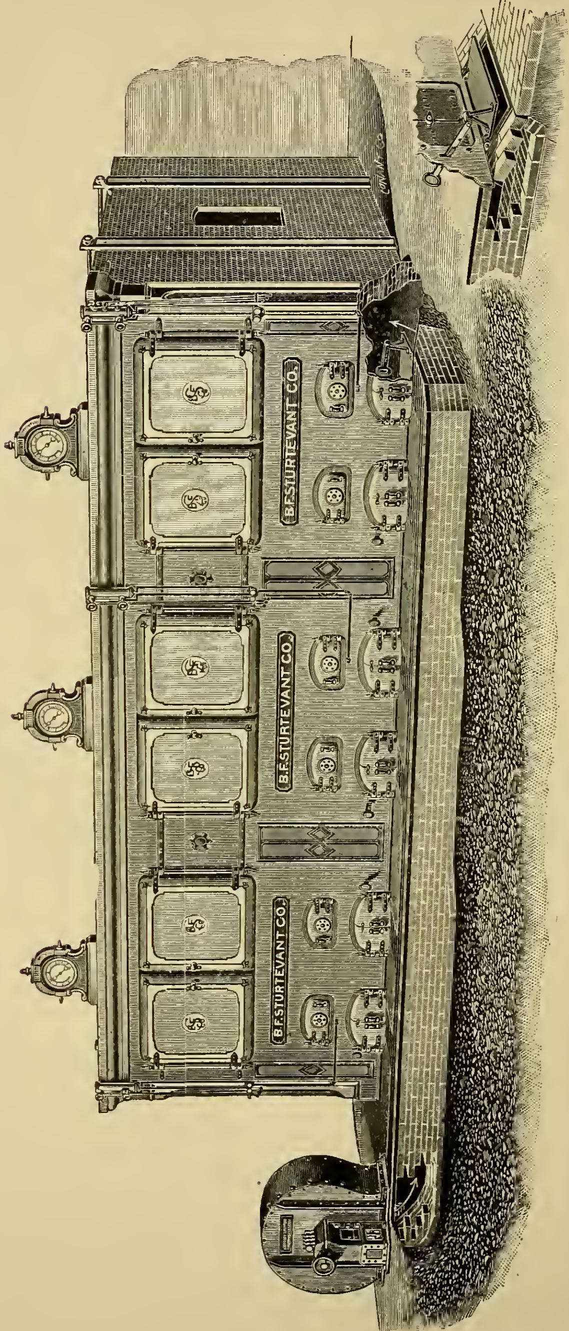


Fig. 1. Forced Draft Arrangement.

In a forced draft installation, as illustrated in Fig. 1, the fan may be so designed that the air is discharged into an underground

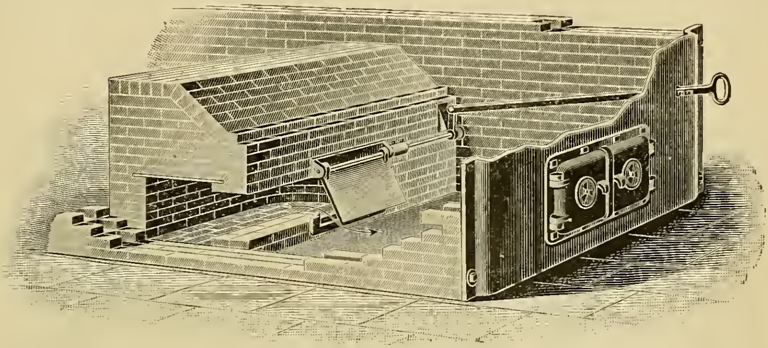


FIG. 2. ASHPIT DAMPER IN BRIDGE WALL.

brick duct, extending along the front of the boilers, whence it passes through branch ducts to the individual dampers in the ashpits.

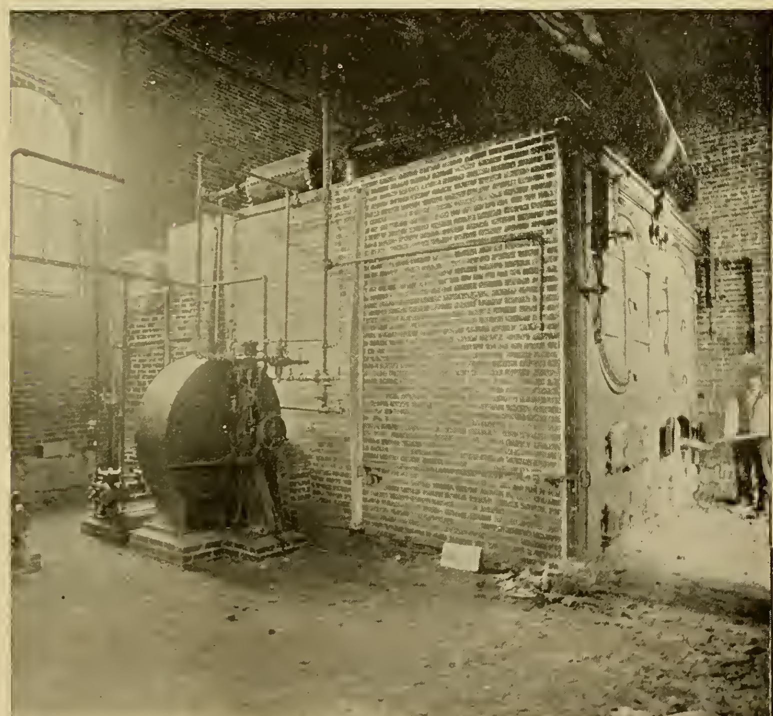


FIG. 3. FORCED DRAFT PLANT WITH HOLLOW BRIDGE WALL.

One of these, with its means of operation, is very clearly shown at the right of the cut. Such an arrangement is readily applicable to a boiler plant already installed.

In a new plant, however, the bridge wall may be left hollow and utilized as an air duct, a damper, of the form shown in Fig. 2, being employed and operated from the front by means of the notched handle bar. The effect of both forms of damper is to spread the air evenly over the entire bottom of the ashpit, whence

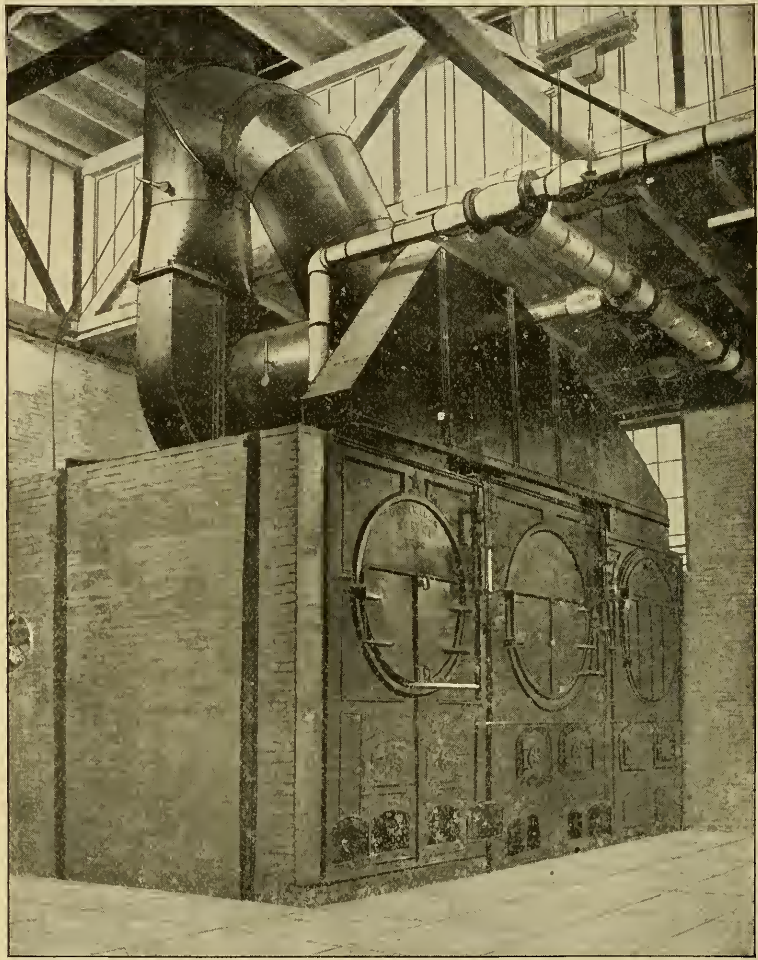


Fig. 4. Induced Draft Plant with Single Fan.

it rises in even volume at low velocity. A plant arranged on the forced draft principle, designed to discharge through a hollow bridge wall, is clearly shown in Fig. 3.

Under the vacuum or induced method, the fan is introduced as a direct substitute for the chimney, creating a vacuum in the furnace and drawing therefrom the gases generated in the process

of combustion. As the draft is thus rendered positive and practically independent of all conditions, except the speed of the fan, it is necessary to provide only a short outlet pipe to carry the gases to a sufficient height to permit of their harmless discharge to the atmosphere.

In practice, the capacity of an induced draft fan must vary with the temperature of the gases it is designed to handle. Therefore the density, which varies inversely as the absolute temperature, should enter as a factor in all such calculations.

Various arrangements of induced draft are usually possible with an ordinary boiler plant. As a rule, the simplest arrangement

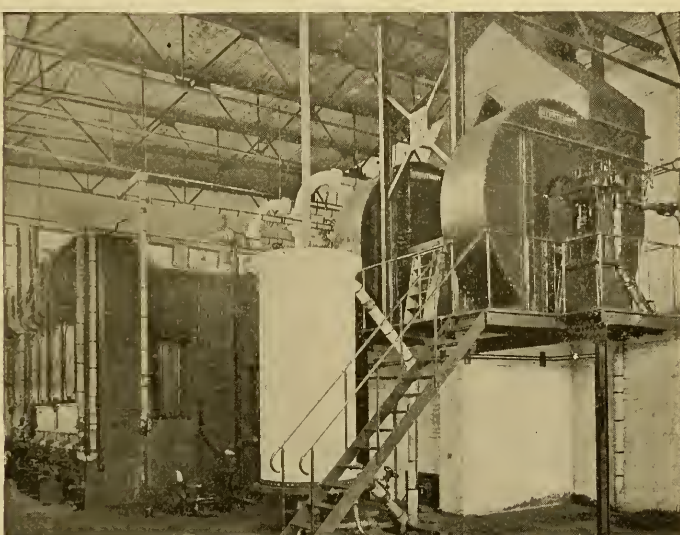


Fig. 5. Induced Draft Plant with Duplex Fan.

consists in placing the fan or fans immediately above the boilers, leading the smoke flue directly to the fan inlet connection, and discharging the gases upward through a short pipe extending just above the boiler house roof.

The arrangement of a single fan after this manner is shown in Fig. 4, while a duplex induced draft plant, having two fans, each of sufficient capacity to produce the required draft for the entire battery of boilers, is presented in Fig. 5. In both instances the fans are provided with direct-connected engines having water-cooled journals.

The ultimate efficiency of a steam boiler is dependent upon three principal factors:

First. The primary cost of the entire plant and the fixed charges thereon.

Second. The quantitative efficiency of the plant as a means of burning the fuel supplied, and transferring its heat to the water evaporated.

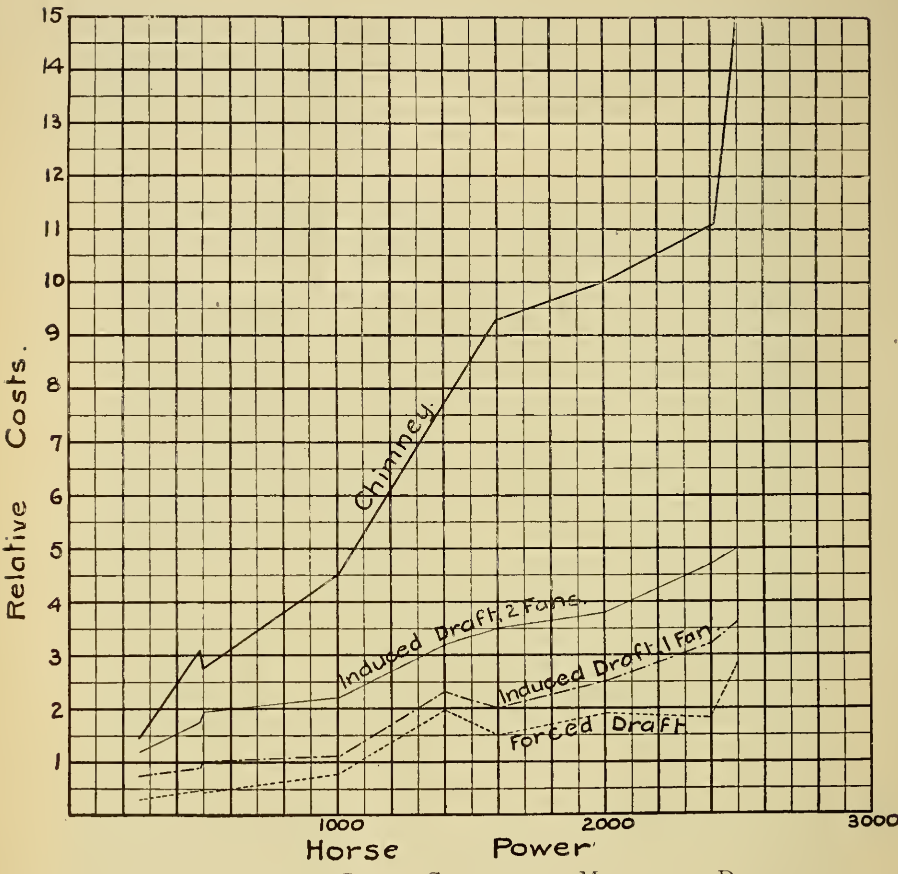


FIG. 6. COMPARATIVE COST OF CHIMNEY AND MECHANICAL DRAFT.

Third. The operating expense including the fuel.

In addition there are always distinct advantages or disadvantages which, while of marked importance, can be measured only qualitatively in their relation to the superiority of any given arrangement or appliance.

In so far as mechanical draft has a direct influence on any of these factors it is the purpose to consider here its ultimate effect upon the efficiency of the steam boiler plant to which it may be applied. Naturally, the question of primary cost first enters into

the consideration, and secondly, that of maintenance and operation, while all three of these items are to be viewed in the light of the efficiency secured. In the matter of first cost comparison is fundamentally made between the cost of a chimney and that of a mechanical draft plant, which may be introduced as a substitute.

In the accompanying curves, Fig. 6, are presented the relative costs of chimneys and of equivalent mechanical draft equipments in a number of boiler plants widely different in character and rated capacity. In certain of these the cost of the existing chimney is known, and that of the complete mechanical draft plant is estimated, while in others the cost of the mechanical draft installation is determined from the contract price, and the expense of a chimney to produce equivalent results is calculated. Costs are shown for both single, forced and induced engine-driven fans, and for duplex engine-driven plants in which either fan may serve as a relay. An apparatus of this latter type is evidently most complete, and is necessarily the most expensive. It finds its greatest use where economizers are employed.

An average for the costs for these nine representative plants shows the total expense for installing a forced draft plant to be only 18.7 per cent., that of a single induced fan and accessories 26.7 per cent., and that of a complete duplex induced draft plant 42 per cent. of that of a chimney. In each case a short steel plate stack is included.

In other words, if a chimney be estimated to cost $10,000, there could be saved, on a basis of these averages, the respective amounts of $8130, $7330 or $5800 in the first cost, according to which system of mechanical draft is substituted.

For a good steam boiler plant it is fair to assume the following as average fixed charges:

Interest	5	per cent.
Depreciation and repairs	4½	"
Insurance and taxes	1½	"
Total	11	per cent.

Experience has shown that these figures also hold good for a well-designed mechanical draft apparatus, and are therefore accepted here. On the other hand the fixed charges on a chimney may be fairly assumed as,—

Interest	5	per cent.
Depreciation and repairs	1½	"
Insurance and taxes	1½	"
Total	8	per cent.

COMPARISON OF COSTS AND FIXED CHARGES.

Method of draft production.	First cost. Amount.	First cost. Ratio.	Annual fixed charges. Amount.	Annual fixed charges. Ratio.
Chimney	$10,000.00	$1.00	$800.00	$1.00
Induced draft plant (2 fans)	4,200.00	.42	462.00	.58
Induced draft plant (1 fan)	2,670.00	.267	294.00	.37
Forced draft plant (1 fan)	1,870.00	.187	206.00	.26

The fact that the mechanical draft apparatus can usually be placed overhead or on top of the boilers where it occupies no valuable space, and that the space otherwise occupied by the chimney is at the same time rendered available, makes possible a further saving which is necessarily dependent upon the land values.

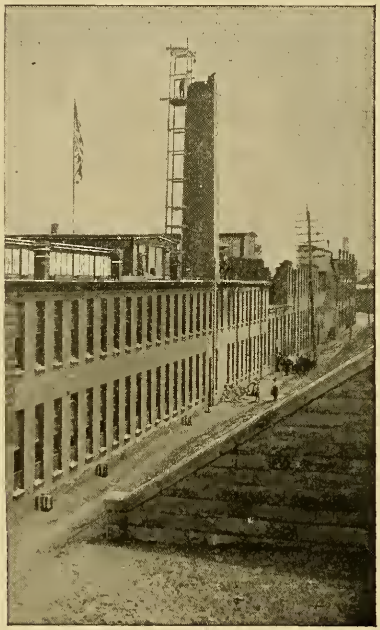


FIG. 7. SHOWING SMOKE PIPE TO RIGHT OF CHIMNEY.

Within city limits it may readily amount to $1000 in a plant of a thousand horse power.

The relative proportions of a brick chimney and of the smoke pipe required when mechanical draft is introduced are forcibly shown in the accompanying illustrations, Figs. 7 and 8. The removal of the boilers to a position too far distant from the chimney to permit of its longer fulfilling its office naturally presented an excellent opportunity for the substitution of an induced draft fan, and the subsequent removal of the chimney. The present stack or smoke pipe, barely visible in Fig. 8, extends only 31 feet above the ground.

A concrete case illustrating the possibilities of mechanical draft is presented in the accompanying drawings, Figs. 9 and 10. These show a plant of 2400 horse power of modern water-tube boilers, 12 in number, set in pairs and equipped with economizers. The left-hand drawing indicates the location of the chimney 9 feet in internal diameter by 180 feet high, designed to furnish the necessary draft. To the right is the same plant with a complete duplex induced draft apparatus substituted for the chimney and placed above the economizer connections. Each of the two fans is driven by a special engine, direct-connected to the fan shaft, and each is capable of producing draft for the entire plant. A short steel plate

FIG. 8. SHOWING SMOKE PIPE TO RIGHT OF AND BELOW FLAG.

stack unites the two fan outlets and discharges the gases just above the boiler house roof. All of the room necessary for the chimney is saved, and no valuable space is required for the fans.

COST OF BOILER PLANT WITH CHIMNEY.

12 boilers	$37,000.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	9,000.00
Automatic damper regulators and dampers	400.00
Chimneys, including foundations	10,700.00
Boiler house	11,500.00
Total	$79,100.00

RELATIVE COSTS.

Chimney Draft.

Cost of chimney	$10,700.00
Cost of damper regulators and dampers	400.00
	$11,100.00

Mechanical Draft.

Cost of mechanical draft plant complete	4,700.00
Saving by using mechanical draft	6,400.00
	$11,100.00

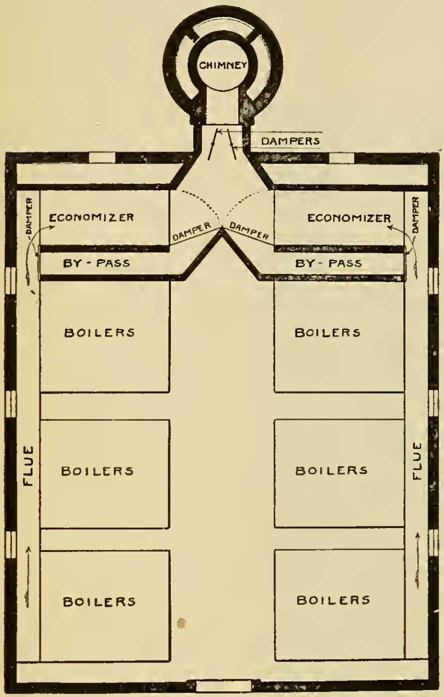


FIG. 9. 2400 H. P. BOILER PLANT OPERATED BY CHIMNEY DRAFT.

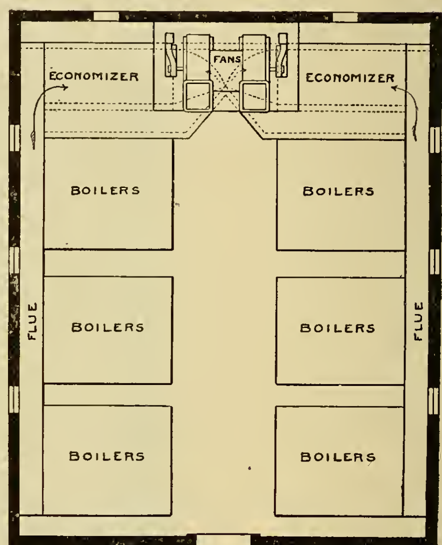


FIG. 10. 2400 H. P. BOILER PLANT OPERATED BY MECHANICAL DRAFT.

The costs of the chimney and the mechanical draft apparatus, which are also indicated, show a saving in first cost of $6400 as the result of using the mechanical draft method.

The intensity of draft produced by a fan and the readiness and economy with which it may be secured make it a simple matter to maintain a combustion rate higher than that ordinarily obtained with a chimney.

The accompanying table, which presents the various pressures, expressed in pounds per square foot, experimentally determined by Professor Gale, for a certain stationary boiler, clearly indicates

that nearly all of the draft is required to overcome resistances incident to the maintenance of a higher rate. Boilers have naturally been proportioned to meet these conditions, but it is manifest that, by changes in design, or by the introduction of heat-abstractors, they may, under the influence of mechanical draft, be readily operated at considerably above their original ratings, with substantially the same efficiency. As a result it is possible to obtain a given output with a plant of less size and first cost than is possible with a chimney. This is particularly true where the steam consumption is liable to sudden fluctuations for comparatively short periods.

FURNACE PRESSURES.

Required to produce entrance velocity (3.6 feet per second)	0.013
Required to overcome resistance of fire grate	0.91
Required to overcome resistance of combustion chamber and boiler tubes	1.23
Required to overcome resistance in horizontal flue	0.06
Required to produce discharge velocity (11.2 feet per second)	0.085
Total effective draft pressure	2.298
Back pressure due to friction in stack	0.19
Total static pressure produced by chimney	2.488

The typical boiler plant already presented will serve as an excellent illustration. Suppose it is determined to omit two of the twelve boilers, say one from each pair at the end farthest from the economizers, and to force the remaining boilers up to the original rating, which can be easily done by mechanical means, as a substitute for the chimney. This will decrease the rating to 2000 horse power, or by $16\frac{2}{3}$ per cent. The volume of air required per pound of coal, with the higher combustion rate, deeper fires and mechanical draft under automatic control, will be somewhat less than that with the chimney, while if the economizers remain the same, their capacity relative to the heating surface of the boilers will be greater, so that the ultimate waste by heat in the escaping gases will certainly not be increased.

RELATIVE COSTS.

2400 Nominal Horse Power Plant, with Chimney Draft.

12 boilers	$37,000.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	9,000.00
Automatic damper regulators and dampers	400.00
Chimney, including foundations	10,700.00
Boiler house	11,500.00
	$79,100.00

2000 Nominal Horse Power Plant, with Mechanical Draft.

10 boilers	$30,833.00
2 economizers	10,500.00
Boiler and economizer settings and by-passes	8,500.00
Boiler house	11,000.00
Mechanical draft plant complete	4,700.00
Saving by using mechanical draft	13,567.00
	$79,100.00

The original costs under the two conditions will be about as indicated. A total possible saving of $13,567 is thus shown, of which $7167 is due to the reduction in nominal horse power made possible by the introduction of mechanical draft.

A problem that has to be faced sooner or later in most boiler plants is that of increased capacity. This differs from that just presented in that the chimney already exists, and it becomes a question whether the desired result shall be obtained by forcing the existing boilers or by adding to their number. The former method demands an increase in intensity of draft, which with a given chimney, operating well up to its capacity, can only be obtained by considerable increase of height at excessive expense, while with either method a larger volume of air is required. As a result increased output frequently demands not only more boilers, but a new or higher chimney. Here mechanical draft steps in and presents a simple solution of the problem:

RELATIVE COSTS.

2800 Nominal Horse Power Plant with Chimney Draft.

2 additional boilers	$6,167.00
Settings, etc., for 2 boilers	1,250.00
Addition to building, etc	2,700.00
	$10,117.00

2400 Nominal Horse Power Plant with Mechanical Draft.

Fan, dampers and ducts	$1,500.00
Saving by using mechanical draft	8,617.00
	$10,117.00

Considering the matter of increased output solely in the light of comparative cost between the introduction of more boilers or the introduction of mechanical draft, and disregarding any possible cost of change in the chimney, we may again take for illustration the plant of 2400 rated horse power. Suppose it is desired to increase its capacity to 2800 horse power, or by 16⅔ per cent. Then the relative costs under the two conditions will appear as here indicated.

The saving actually secured by providing surplus capacity in light, rapid-running fans, instead of in ponderous boilers, and the higher efficiency of combustion obtained under proper arrangements with mechanical draft, is most clearly shown by experience in the merchant and naval marine. Here the matter of weight and of space occupied is of great importance. Every pound in weight, or foot of space saved leaves just so much more available for coal and cargo.

We may now turn to that portion of our discussion which relates to the quantitative efficiency of a boiler plant. No greater waste occurs in modern steam-boiler practice than that which is inherent in the employment of a chimney for the production of draft,—namely, the loss of heat in the escaping gases. As the chimney depends for its action upon the maintenance of a temperature difference between the internal gases and the external air, it is manifest that with a chimney this waste can never be eliminated. It may be palliated, it is true, by the building of higher chimneys, so that the same intensity of draft may be obtained with a lower stack temperature. But such means of providing for the utilization of the otherwise waste heat is expensive. For instance, if, with an external temperature of 60°, and an internal temperature of 500°, sufficient intensity of draft is produced by a chimney 100 feet high, it will require a height of 175 feet to produce the same draft when the temperature of the gases is reduced to 250°. In addition the means provided for extracting this heat will increase the resistance, and provisions for overcoming the same will have to be made by greater chimney height.

In the case of a fan, however, the power expended as measured in heat units necessary to produce the same results may, under ordinary conditions, be only about one-seventy-fifth of that necessary with a chimney. In other words, the fan renders available for utilization practically all of the heat wasted by the chimney, while it possesses the further advantage of readily creating the additional draft requisite when heat-abstracting devices are introduced.

Messrs. Donkin & Kennedy in seventeen independent boiler tests found the heat lost up the stack when no economizer was used to range between 9.4 per cent. and 31.8 per cent. of the total heat of combustion. As it is not practicable to cool the gases to atmospheric temperature, it is evidently impossible to utilize all of the heat, but the ordinary economizer should, with mechanical draft, show a saving of between 10 and 20 per cent.

The average results obtained by Roney from tests of nine plants equipped with economizers and mechanical draft were as follows:

Temperature of gases entering economizer	526.3	degrees.
Temperature of gases leaving economizer	269.6	"
Decrease in temperature of gases	256.7	"
Temperature of water entering economizer	150.4	"
Temperature of water leaving economizer	297.1	"
Increase in temperature of water	146.7	"
Fuel saving in per cent		14.64

Although not developed to the same extent as the economizer, the air heater, by which the heat is transferred from the gases to the air supplied to the furnace, has been introduced to a considerable extent with satisfactory results. In experiments with the Marland

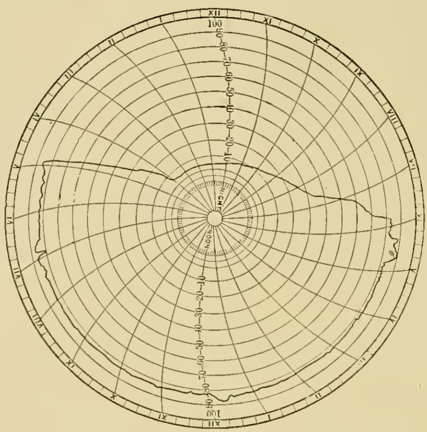


Fig. 11. Steam Pressure Chart for Induced Draft Plant.

apparatus Hoadley showed that the waste of the flue gases could be reduced to only 5 per cent. of the total heat value of the fuel with an accompanying expenditure of only 1 per cent. of the steam generated for driving the blower.

The importance of mechanical draft in the adoption of means for utilizing the waste heat is well exemplified in the introduction of retarders and of ribbed tubes. Both of these increase the resistance, and almost invariably require fan draft to enable them to create the saving of 5 to 10 per cent. which may be thus secured.

The facility with which the intensity of the draft and the volume of air supplied can be regulated when a fan is employed for draft production has always been recognized as one of the most valuable characteristics of this method. Such regulation makes possible the most perfect distribution of the air, and its reduction

to the minimum amount which will produce satisfactory combustion.

Variable draft is necessary to maintain a constant steam pressure. This is evidenced by the accompanying charts from a mechanical draft plant. Fig. 11 illustrates the practical uniformity of steam pressure maintained, while Fig. 12 indicates the considerable fluctuations of the draft required. The operation of the fan is automatically regulated so that the slightest variation in the steam pressure causes considerable change in the speed, and consequently in the draft.

For the mere chemical requirements of the combustion of one pound of ordinary coal, about 12 pounds or 150 cubic feet of air is required. But under the conditions of chimney draft this amount is greatly exceeded. Donkin & Kennedy showed in the results

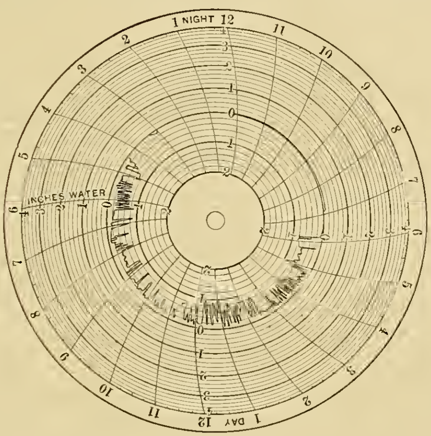


Fig. 12. Draft Pressure Chart from Induced Draft Plant.

of sixteen tests that the air supply ranged from 16.1 pounds to 40.7 pounds.

The theoretical effects of an excess of air upon the combustion of an ordinary anthracite coal are such that the ideal temperature in the heart of the fire decreases with the excess, while the relative weight of the products of combustion becomes greater. Although the initial volume increases with the excess it is to be noted that the relative volume, after heating, remains practically constant because of its lower temperature and consequent greater density. As the gases pass onward through the tubes they become cooled, but those of higher temperature part most readily with their heat, and at the same time their volume and consequent velocity are reduced, still further facilitating heat transmission. On the other hand, the gases of lower initial temperature transmit their heat less

rapidly, and the final result is that within practical limits the temperature of the escaping gases is highest with the greatest excess of the air supply.

The fact just presented points toward the economy to be secured by comparatively high rates of combustion when the proper rate of heating surface to grate surface is provided. A high combustion rate manifestly requires a thicker fire, which in turn presents a better opportunity for contact between fuel and air with consequent economy in the supply of the latter. Less air results in a more intense fire, a higher furnace temperature, a greater transmission of heat to the water within the boiler, and a resultant higher evaporative efficiency. But the thicker fire requires a greater intensity of draft to overcome the increased resistance, while the relatively smaller area for passage of air necessitates a higher velocity of that air, and, furthermore, the increased intensity to produce this velocity must be proportional to the square of the rate of flow. This condition is most readily met by the fan, which, under normal conditions, produces an intensity exceeding that of an ordinary chimney, and which can, without trouble, maintain the highest practicable rate of combustion.

Whitham found that with a certain mechanical stoker in which the air distribution was almost ideal, an excess of 85.6 per cent. was used when the rate of combustion was 12 pounds, while almost perfect evaporative efficiency was maintained when the rate was 45.4 pounds, and the air supply actually 11.2 per cent. below the chemical requirements.

The actual fuel saving resulting from the introduction of mechanical draft is forcibly shown by the accompanying record of eight voyages of the same vessel under identical conditions, except as regards the means of draft production. It is to be noted that the total consumption of coal per day was reduced 13 per cent., while the time occupied in making the voyage was decreased nearly 5 per cent. by the substitution of forced draft.

SAVING BY FORCED DRAFT ON STEAMSHIP "DANIA."

Conditions.	Days steaming.	Knots per hour.	Consumption of coal per day.	Consumption for all purposes per day steaming.
Natural draft, 4 voyages........	17.00	7.50	9.73	10.70
Forced draft, 4 voyages.......	16.21	7.58	7.76	9.31

Among the losses incident to combustion, that resulting from the formation of smoke is absolute, for it is equivalent to directly robbing the fire of a part of the fuel from which not only has no heating effect been secured, but upon which heat has actually been wasted in raising it to the temperature of the escaping flue gases.

Fortunately from a purely economic standpoint, this loss seldom, if ever, exceeds 1 per cent. of the total calorific value of the fuel. In fact the prevention of smoke is not to be considered so much in its economic aspect as in its relation to the stringent laws which are being enforced in many communities. It thus becomes a question of life or death, for, unless the smoke is prevented, the boilers cannot be operated. For the prevention of smoke, sharp, intense draft is necessary, properly regulated and capable of furnishing the required amount of air, both below and above the fuel at the very moment when it is most needed. This result can be best secured by the introduction of mechanical draft, which is ordinarily so regulated that the decrease in steam pressure resulting from the opening of the fire doors, the charging of the furnace or the clearing of the fires instantly causes an increase of the speed of the fan and in the intensity of the draft and the volume of air.

A loss incidental to poor draft is that due to the formation of carbonic oxide. The formation of this gas instead of the complete product of combustion, carbonic acid, results from the lack of air, and may under adverse conditions mount up to a resultant loss of 5 or 10 per cent. and over of the calorific value of the coal. Thick fires and large charges of cold fuel are certainly not conducive to the ready flow of air under only slight pressure, such as is maintained with the chimney. Under these conditions any operation of the flue damper, automatic or otherwise, only serves to vary the volume of the air, but in no way increases the intensity of the draft. This can only be secured by some means like the fan, which under automatic regulation increases both the intensity of the draft and the volume of the air when required. As a result, the pressure forces the air in sufficient quantity to all spaces between the fuel, and renders the combustion practically perfect. Numerous tests of the flue gases fail to reveal the presence of any carbonic oxide when mechanical draft is employed.

By far the most important of the factors connected with the operating expense of a boiler plant is the cost of the fuel. When burned under suitable conditions, the decrease in its cost far outstrips the decrease in its efficiency, so that the solution of the problem involves itself with the provision of the proper conditions. As a rule the cheap fuels, like the fine anthracites, require for their combustion an intensity of draft, which the ordinary chimney is incapable of producing. Speaking of the chimney in this connection, Coxe asserted that "It is always very difficult, in fact almost impossible, to obtain with it sufficient blast to burn the smallest sizes of anthracite coal, which require a strong and concentrated draft."

It is here that mechanical draft presents itself as a solution, for it fully meets the most exacting requirements as regards intensity, costs far less for its installation than a chimney of equivalent capacity, and is capable at all times of producing the blast necessary for securing the best results in the furnace.

What these requirements are is evidenced by the accompanying figures from careful tests by Coxe:

RESULTS OF TESTS OF PEA AND BUCKWHEAT COALS.

Kind of coal.	Rate of combustion per sq. foot of grate per hour.	Pounds of water evaporated from and at 212° per lb. of coal.	Air pressure in inches of water.	Maximum limit to size of coal in inches.
Oneida pea coal................	13.63	8.56	0.375	7/8
" No. 1 Buckwheat.......	13.58	7.94	0.5	9/16
" No. 2 "	11.40	8.60	0.625	3/8
" No. 3 "	11.34	8.65	1.04	3/8
Eckley No. 3 "	9.44	8.75	1.125	3/16

These coals, which are among the smallest in size, were burned on a special form of traveling grate, and the air pressure was maintained in the chamber beneath. It is noticeable that with practically constant combustion rate and evaporative efficiency the draft increases very rapidly as the size of the coal decreases.

RELATIVE EFFICIENCIES OF VARIOUS COALS.

Kind of coal.	Water evaporated from and at 212° by 1 lb. of dry coal.	Relative efficiency in per cent. Cumberland = 100.	Cost of coal per ton.	Fuel cost of evaporating 1000 lbs. of water from and at 212°.	Relative efficiency in per cent. measured by cost to evaporate 1000 lbs. Cumberland = 100.
Cumberland	11.04	100	$3.75	$0.1698	100
Anthracite, broken.........	9.79	89	4.50	0.2297	74
Anthracite, chestnut........	9.40	85	5.00	0.2660	64
Two parts pea and dust and one part Cumberland....	9.38	85	2.58	0.1375	123
Two parts pea and dust and one part culm............	9.01	82	2.58	0.1432	119
Anthracite pea.............	8.86	80	4.00	0.2259	75
Nova Scotia culm	8.42	76	2.00	0.1187	156

The comparative efficiency of various coals as determined by Barrus is indicated in the accompanying table, which speaks for itself. The evidence in favor of burning low-grade fuels is conclusive. Such results can, however, only be secured by positive and intense draft.

It is true that as the quality of the coal grows poorer and the size of the particles less, it becomes more necessary to provide some special form of grate or stoker for its proper burning. But

even without an economizer to utilize the waste heat, the burning of cheap fuel by mechanical draft will, under perfect conditions, show a decided saving after due allowance is made for fixed charges on the special furnace arrangements, and for the cost of operating the fan:

ANNUAL SAVINGS RESULTING FROM BURNING CHEAP FUEL, IN 1000 H. P. PLANT.

Water evaporated from and at 212° per lb. of coal.	COST PER TON.														
	$0.50	$0.75	$1.00	$1.25	$1.50	$1.75	$2.00	$2.25	$2.50	$2.75	$3.00	$3.25	$3.50	$3.75	$4.00
11.00	....	....	....	....	....	....	....	....	....	....	4,892	3,669	2,446	1,223	....
10.50	....	....	....	....	....	....	....	....	....	5,474	4,193	2,912	1,630	349	....
10.00	....	....	....	....	....	....	....	....	6,115	4,770	3,424	2 079	734	....	....
9.50	....	....	....	....	....	....	8,240	6,823	5,407	3,991	2,575	1,159	....	....	....
9.00	....	....	....	....	....	9,105	7,610	6,115	4,621	3,126	631	136	....	....	....
8.50	....	....	....	....	10,071	8,491	6,909	5,326	3,743	2,160	578	....	....	....	....
8.00	....	....	....	11,180	9,478	7,797	6,115	4,433	2,752	1,070	....	....	....	....	....
7.50	....	....	12,393	10,599	8,805	7,012	5,218	3,424	1 630	....	....	....	....	....	....
7.00	15,724	13,803	11,881	9,959	8,037	6,115	4,193	2,272	350	....	....	....	....	....	....

The possible savings with low-grade fuels and mechanical draft are still further evidenced by the accompanying table, which shows, for a 1000 horse power plant, the annual saving, based on 312 days of ten hours each, which would result from the substitu-

tion of a cheaper fuel for, say Cumberland coal, costing in round figures $4 per ton, and evaporating eleven pounds of water from and at 212° per pound of coal. Under these conditions the annual fuel expense would be $19,568. If the assumption be made that a coal costing $2.50, and evaporating only nine pounds of water, is substituted, the annual saving would be $4621. The fuel cost of operating the fan, even if the exhaust steam was not utilized and it required $1\frac{1}{2}$ per cent. of the total coal burned, would be only $224, and if this is charged against the saving it would still amount to $4397, a sum sufficient to show a most creditable reduction in operating expense even if there was charged against it any additional labor and the fixed charges on a complete equipment of the special appliances for burning the lower grade fuel. In general practice a mere change of grate bars is sufficient to adapt a boiler for burning almost clear yard screenings by means of mechanical draft.

A reduction of over $125 per week, equivalent to $6500 per year, has been made in actual practice in the case of a boiler plant of 1000 horse power by the introduction of mechanical draft and the burning of yard screenings with a slight mixture of Cumberland.

A very interesting example of the reduction of fuel cost incident to the introduction of mechanical draft here follows. The average load for the second year exceeded by about 30 horse power that of the first year:

RESULTS OF OPERATION OF BOILER PLANT AT HOTEL IROQUOIS, BUFFALO, N. Y.

Without Mechanical Draft.

Time.	Kind of coal.	No. of tons.	Cost per ton.	Total cost of each kind of coal.	Weight and total cost of coal for year.
Dec. 1, 1892, to Nov. 30, 1893.	Hard Coal Screenings	232	$1.25	$1072.45	4751.24 tons.
	Hard Coal Screenings	601.9	1.30		
	Soft Nut	696.95	2.20	$9084.92	$10,157.38.
	Soft Nut	15.04	2.25		
	Soft Nut	1,759.6	2.30		
	Soft Nut	1,445.75	2.40		

With Mechanical Draft.

Time.	Kind of coal.	No. of tons.	Cost per ton.	Total cost of each kind of coal.	Weight and total cost of coal for year.
Dec. 1, 1893, to Nov. 30, 1894.	Hard Coal Screenings	1,299.95	$1.30	$5356.24	5013 tons.
	Hard Coal Screenings	2,610.08	1.40		
	Hard Nut	3.02	3.50	$2333.69	$7680.93.
	Soft Nut	843.03	2.10		
	Soft Nut	255.9	2.20		

Although the annual coal consumption was increased as was to be expected with the lower grade of fuel, yet a reduction of nearly 25 per cent. in the cost was effected.

With the increasing interest in the possible reductions in operating expenses, more attention is being turned to the mechanical stoker, both as a means of more economically and of more uniformly supplying the fuel to the furnace. As incidental to its success, positive and automatically regulated draft is a necessity. This is particularly true in the case of the modern forms of under feed and chain feed machines. The forced method of mechanical draft is generally employed and the necessary arrangements are of the simplest character.

Of the advantages of mechanical draft which are purely qualitative in their character much might be said, but time will not permit. It must suffice to merely refer to the more prominent points of advantage.

When the fan is employed for draft production the steel plate construction, the comparative lightness, the portable character and the absence of heavy foundations render extremely simple its adaptation to the exact requirements. Being portable it is also salable, and hence an asset of real value as compared with the chimney. It may be used either for forced or induced draft and placed where it will occupy no valuable space. It may be operated by direct connected or belted engine or motor, and so proportioned as to produce any desired draft pressure.

In operation the fan is both positive and flexible, independent of the weather, but capable of regulation to the finest degree and of adjustment to the necessities of the fire at any particular moment. A mere increase in the cut-off of the fan engine brings about a result only secured with a chimney at the expense of adding to its height, while a change in the fan speed alters both the volume handled and the intensity of the draft produced.

If this discussion of the influence of mechanical draft on boiler efficiency has rendered clear the factors concerned, it has with equal force shown that this influence is beneficial,—in many ways markedly so. In the light of this fact the present active interest in the subject points to the future consideration of mechanical draft as a most important factor in steam boiler practice.

WATER WASTE.

By Joseph C. Beardsley, Member Civil Engineers' Club of Cleveland.

[Read before the Club, June 13, 1899.*]

Water waste, while it is one of the most annoying difficulties with which the water works engineer comes in contact, can scarcely be considered an engineering problem, for the reason that the solution of it is perfectly obvious and the means of preventing it easily available, providing only that the administrative officers are sufficiently broad-minded and intelligent to appreciate the situation. It is essentially an administrative rather than an engineering question, and the only reason for presenting such a subject to an audience of engineers is that it usually falls to engineers to educate the administrative officers up to the point of applying the one infallible remedy and the water takers to accepting it as the only just means of estimating their water rates.

Cleveland was fortunate in this respect, and meters have been in service here for considerably over twenty years without serious objection from either administrative officers or water takers.

According to American ideas, air and water are on about the same plane,—the supply of each should be equally free and limited only by the demand, no matter of what nature,—and this idea was perfectly proper fifty years ago, when every man had his own well or running stream from which to draw his supply, which was usually limited only by his physical ability in drawing it. Even then, however, no man drew water from his well for the pleasure to be derived from spilling it on the ground.

Now, with the development of the modern city, we have all this "drawing of water" accomplished for us, and instead of expending physical effort we pay for it in cash.

We are able to have a supply at any point we desire it, and it comes with the simple turning of a cock; but with all this ease of accomplishment comes the idea that it is not incumbent on us to use any discretion in the consumption of what comes to us so easily.

This idea is fostered, too, by the manner in which payment is made, in the great majority of cases, for this service. When one has to pay only a certain fixed rate, based on the number of rooms or fixtures, it is easy to fall into the habit of thinking that it really makes but little difference how much water is consumed and to

*Manuscript received December 6, 1899.—Secretary, Ass'n of Eng. Socs.

procrastinate going for the plumber if any of the fixtures get out of order and run continuously.

If any qualms of conscience do make themselves felt, we reason that our neighbor is probably doing the same thing anyway, and ask ourselves why shouldn't we? or, again, somewhat contradictorily, we feel that "just our one faucet running don't waste much water." We should stop the leak very quickly, however, if the supply depended on our own physical exertions, or if we had to pay for it according to the amount we consumed.

The operating expenses of the Cleveland Water Works for the year 1897 were $182,694.22.

The total cost of the plant, including that year, was about $8,500,000, the interest on which, at 5 per cent., which would be a fair average for the period covered, would be $425,000, making a total of $607,694.22. The total water pumped during 1897 was 17,658,470,308 gallons.

This makes the cost of furnishing water about 3.4 cents per 1000 gallons, and in these figures no allowance is made for the cost of pipe extension, river tunnels and other minor construction which is paid for out of the income without the issue of bonds.

This shows that while water is a cheap commodity, it still does cost something, and it is perfectly apparent, since the expenses are nearly proportional to the amount of water pumped, that water rates can be reduced only by reducing the amount of water pumped, or by cutting off all the improvements that are paid for out of the revenue.

In Cleveland the minimum water rate with a private meter (one set at the expense of the consumer) allows a consumption of 150,000 gallons at a cost of $8.00 per year.

These meters are set almost invariably on dwellings, and form a fair basis of estimate of the necessities of a family. At this rate each service would consume 410 gallons per day, and, estimating six consumers to a service, would allow a per capita consumption of 68 gallons per day. This would seem to be a liberal allowance, and experience has shown that the consumption on private meters seldom reaches this rate. In the few cases where it is exceeded it is almost invariably found that there has been a leak or some unusual condition of consumption. Dwellings where private meters are in service would pay by assessment from $12.00 to $20.00 or more, and under present conditions this rate cannot be reduced without creating a deficit in the revenues of the department.

An expert commission appointed in the city of London to investigate the subject of water supply estimated that 42 gallons per

capita per day was a liberal supply, and in Paris the actual consumption is 36 gallons. In Cleveland the consumption in 1897 was 136.3 gallons per capita per day, which was the highest in the history of the city except for 1895, when it was 136.6 gallons; 24.4 per cent. of the total pumpage for 1897 was metered, and this may fairly be taken to represent the amount of water consumed for manufacturing and other similar purposes. Deducting this from the average for 1897 leaves 103 gallons on the unmetered services. Assuming our minimum private meter rate as a fair estimate of a liberal supply (68 gallons), this would leave 35 gallons, or 34 per cent. of all water not metered; and, of course, the showing would be much worse if we were to take the London or Paris figures, or even those of the actual consumption on our private meters. This cannot all be assumed to be waste, for we furnish a large amount of free water for municipal and charitable institutions, to say nothing of flushing paved streets and sewers and puddling trenches; but a large proportion of it is undoubtedly waste.

In many other cities the showing is much worse, notably in Philadelphia, where our friend Mr. Trautwine has been making a valiant, but so far, I believe, unsuccessful, fight for the introduction of meters.

In a paper read by him before the Engineers' Club of Philadelphia, in October, 1898, some startling figures are given. In one district of Philadelphia, containing 142 modern seven-room houses, with 539 inhabitants and 782 water appliances, 22 of these appliances were found leaking slightly and 32 were found running continuously.

The water consumed in this district during twenty-four hours was 119,800 gallons, or 222 gallons per capita per day, of which he estimates that only 16,120 gallons, or 13.4 per cent., was used, the remaining 86.6 per cent. being wasted. The figures for water used look rather small, as they allow only about 30 gallons per capita per day; but in any event it is easy to see that a large proportion of the water furnished to this district was wasted.

In another district a similar examination showed that 63 per cent. of all the water furnished to it was wasted.

The average daily consumption in Philadelphia has risen from 36 gallons per capita in 1860 to 215 gallons in 1897. Practically no meters are in service there.

In Cleveland the average daily consumption has risen from 7.75 gallons per capita in 1857 to 136.3 gallons in 1897, the increase being practically continuous from year to year.

Following is the daily per capita consumption in 1890 of several cities:

Allegheny, 238 gallons, with no meters in service; Buffalo, 186 gallons, with .02 per cent. of taps metered; Richmond, 167 gallons, with 1.4 per cent. of taps metered; Detroit, 161 gallons, with 2.1 per cent. of taps metered. Milwaukee commenced in 1875 with an average consumption of about 3,000,000 gallons per day, reached a maximum of 35,000,000 gallons per day in 1894 and has since declined, the maximum in 1897 being a little over 26,500,000 gallons per day, an average of 88 per capita. This was for the single month of July, and the average for the year is only 79 gallons per capita per day. Meters have been in very general use in Milwaukee since about 1890, and in 1897 there were 20,000 in use, which I should estimate to include at least 50 per cent. of all taps. It is noticeable in the foregoing instances how the daily average decreases as the number of meters increases.

A still more striking illustration of the effect of the introduction of meters is furnished by the experience of Detroit. From 1870 to 1888 the consumption increased from 64 gallons per capita per day to 204 during the latter year. During 1888 the setting of meters was commenced, and it has been since steadily continued, until in 1898 there were 5393 in service on 10 per cent. of the taps, and including 20 per cent. of the consumption. Since 1888 the consumption per capita per day has varied between 172 gallons in 1889 and 124.5 gallons in 1897. If the meters had not been set it is safe to assume that the increase in consumption would have risen at the rate that prevailed at the time of the setting of the meters. If this had been the case, it would have been necessary to make additions to the plant that would have involved an expenditure of $600,000 and an increase in operating expenses of $11,000 per year.

The meters are read and kept in repair without noticeable increase in the operating expenses, and they cost only $151,000.

I might go on indefinitely to cite such examples, but enough has been said, I think, to show that in cities where meters are not generally in use there is a rapidly increasing consumption of water, which is largely pure waste, and which involves large additional expenditures every year for plant and operation, while there is no such increase in cities where meters are in general use.

It may be of advantage now to inquire into the manner in which this waste occurs.

Quoting again from Mr. Trautwine's paper, a faucet leaking one drop per second wastes 5 gallons daily; one dropping constantly, but not running a continuous stream, 9 gallons; a third,

running the smallest possible steady stream, 14 gallons, and so on up to one running full opening, 2357 gallons in twenty-four hours.

To come to more concrete examples, we had occasion some years since to meter a number of church schools where there were flagrant wastes of water. On one of these the assessment was $10.00 per year. In ten days the meter had registered 14,500 cubic feet, and if this rate had been continued the bill would have been $208.80 for one year. Notices and warnings had been served repeatedly on the school authorities, but it was not until the meter was set that any serious effort was made to put a stop to the waste. During this metering of the church schools, however, some political toes must have got trodden upon, for we got an order that no more meters must be set without the express sanction of the Mayor. Fortunately the worst offenders had been metered by that time.

A more recent case occurred last month on Merwin street. A foreman had been sent to set a meter for a new manufacturing concern, and by mistake, there being two connections in front of the place, got the meter on the connection for the place next door.

As it was in a district which it is desired to meter generally, no great harm was done, and the meter was allowed to remain. Next day the foreman went to set the other meter, and incidentally took a reading of the first one, finding a consumption of over 1000 cubic feet in less than twenty-four hours. The assessment rate on this place was $7.00 per year. The meter rate at the rate of consumption for the first day would have been $146, but an investigation revealed a water closet that was running constantly and it was immediately shut off.

Still another case was found in a peculiar way. A main was being laid in a certain street, and in the course of operations it became necessary to cut through a sewer connection coming from a saloon. A constant stream of water was found running in the sewer, and the saloonkeeper claimed to be totally unable to put a stop to it.

The flow was finally stopped by shutting off the water connection for the place.

This was thought to be a favorable location for a meter, and one was accordingly set.

The reading of the meter three days after it had been set was 3310 cubic feet, and the meter was going constantly. The assessment rate on this place was $30.50 per year. The meter rate, unless the waste is stopped, will be about $160.

If the annual diagram of daily consumption for a large city is studied in connection with the daily changes of temperature, it will

be observed that the pumpage runs up with extreme high temperature and also with extremely low temperatures. During periods of extreme cold the waste is due, of course, to the practice of allowing the water to run to keep it from freezing. With the high temperatures the increase is due to excessive sprinkling, to the very general tendency to allow the water to run until it becomes cool for drinking and to the practice of using the water in lieu of ice for cooling purposes. One summer not long since the owner of several large tenement buildings was notified that the consumption on one of his buildings was running to quite an unusual figure, and he desired us to investigate the cause of it. We did so, and found six out of about thirty tenants using their bathtubs as refrigerators. Perishable provisions were put in closed vessels, and then the water was allowed to run constantly over them to keep them cool. All other fixtures in the building had self-closing cocks, so the bathtubs had perforce to be utilized.

Cleveland is not by any means one of the most generally metered cities in the country, but that meters have been set with a consistent regard for measuring the large consumers is shown by the fact that with only about 4 per cent. of the taps metered 24.4 per cent. of the entire pumpage is measured; and the policy at present is to continue, steadily if not rapidly, to place meters in the older sections of the city, where the plumbing is most apt to be defective and where experience has taught us that there is the greatest unnecessary waste of water.

DISCUSSION.

C. O. Palmer.—What is the life of those meters?

J. C. Beardsley.—We figure this by work done by the meter rather than by time. For a $\frac{3}{4}$-inch meter, the smallest size used by us, we have taken 1,000,000 cubic feet, but I think this too high. For a 4-inch meter 40,000,000 cubic feet has been our standard, but I am of the opinion that this is too low for a Worthington meter.

C. S. Howe.—What is the accuracy of the meters?

J. C. Beardsley.—Meters are required to register within about 1 per cent. when new; after wear they register less. The first cost of the meter is from $15.00 to $20.00 (depending on the kind) for a $\frac{3}{4}$-inch meter, and the cost of setting is about $15.00. When set at the consumer's expense he pays 40 cents per 1000 cubic feet of water, with a minimum charge of $8.00 per year. Private meters may be set in basements, and the cost of this is seldom over $5.00.

C. O. Palmer.—How often are the meters replaced?

J. C. Beardsley.—They are left in until they register the

amount we have estimated to be the limit for each size, unless there are other reasons for changing.

M. W. Kingsley.—Many kinds of meters have been tested as to durability; a Worthington $\frac{3}{4}$-inch meter was run to 3,000,000 cubic feet, with tests as to accuracy every 100,000 cubic feet. When it had registered 1,000,000 cubic feet it was within 8 per cent. of accuracy.

Robt. Hoffman.—How are they tested as to accuracy?

J. C. Beardsley.—By running water from meter into a graduated tank in different-sized streams from 1-16-inch to full size of the meter.

A. A. Skeels.—Does the meter affect the pressure?

J. C. Beardsley.—Very little.

John C. Trautwine, Jr. (correspondence).—Touching the statement in my paper presented to the Engineers' Club of this city October 1, 1898, that in the district mentioned only thirty gallons per capita per day were really used, Mr. Beardsley refers to this estimate as looking "rather small," and it is therefore proper to state how the estimate was formed. The measurement of the consumption of the district was made by means of the Deacon waste water detector (described in Proceedings Institution of Civil Engineers, London, Vol. XLII, 1874-5, and in Proceedings Engineers' Club of Philadelphia, Vol. XIII, No. 4, January, 1897), which gives a continuous graphic record of the consumption. As the district examined contained only small dwelling houses, "the quantity running during the night (say from midnight to 2 or 3 A.M.), as detected by the Deacon meter, was considered as wasted, and it was assumed that during the day the waste went on at the same rate." (Mr. Allen J. Fuller, assistant in charge of distribution, in report of Bureau of Water, Philadelphia, for 1895, page 196.) The waste thus estimated amounted to 192 gallons per capita per day, leaving out of the total of 222 gallons only 30 gallons for "use". That this estimate is probably not much too low is indicated by the fact that meter observations continued for more than three years on a suburban dwelling with lawn, and occupied by a family of eight persons, keeping one horse, showed an average daily per capita consumption of only $34\frac{1}{2}$ gallons. In this case the payments were by schedule rates, the meter being used only for the purpose of gaining information.

Noting Mr. Beardsley's remark that "practically no meters are in service" here, it may be well to state that at the close of 1898 1481 meters were in use, but these were all on manufacturing establishments or other large consumers, Councils not permitting the adjustment of water rent on dwellings by meter.

GRADE CROSSINGS.

By Augustus Mordecai, Member Engineers' Club of Cleveland.

[Read before the Club, December 26, 1899.*]

In the discussion of the question of eliminating grade crossings of highways with railroads we must be careful to avoid prejudice. It is hard to overcome the natural impulse to make the corporation bear as much of the burden as possible, whether it is right or wrong to do so. "The corporation can afford it," we say. It is hard even for an employe to divest himself of this feeling, and still more so for one not so employed. Often we notice an employe throwing away as worthless a bolt, for example, that has lost a nut; but if the bolt belongs to his bicycle, how carefully he preserves it for future use.

Even to the most wealthy, the expenditure of millions of dollars must be a matter of careful and judicious thought, not lightly to be entered into.

Let us see what are the rights of the parties, the public and the railroads, in the highway. They are equal as far as occupancy is concerned, and both can go their ways, provided that in so doing neither interferes unreasonably with the other. All are obliged to use caution in the use of the common highway. The individual must be careful he does not take any unnecessary chances in crossing the tracks of the railroad. The electric company, if there is one, must see that its conductor knows that the way is clear before he allows its car to cross; and the railroad company must, by watchmen and gates, or by bell and whistle, warn the public, and use every precaution to have the way clear before its train crosses the highway. Neither of the parties must obstruct the crossing for an unreasonable length of time, consequently all would be benefited equally by the elimination of the grade crossing if it were not for certain conditions not common to both. By the abolition of the grade crossing the public saves time, annoyance due to delays or to precautions necessary for the prevention of accident, and damage caused by the accident itself. A very large proportion of accidents (judging from the records of the Erie Railroad, as high as 60 per cent.) is due to the contributory negligence of the individual. The street car company saves time—not a large item, as the man are paid by the trip—and the liability of accident, which is a much more important consideration with them than with the steam railroad, as its car is weaker and the passenger much more liable to injury.

*Manuscript received December 30, 1899.—Secretary, Ass'n of Eng. Socs.

The steam railroad saves the expense incident to watching the crossing, an expense which legally, but perhaps not justly, it is forced exclusively to bear; the time which would be lost in taking precaution against accident (a larger item than in the case of an electric railroad, as the steam road generally has many highways to cross) and the liability of injury in case of accident, which, as shown, is lower in the case of the steam railroad than with the electric road or with the public. The laws of New York make it obligatory on the part of the parties interested to abolish the crossing if the Board of Railroad Commissioners says it should be abolished; the railroad company paying one-half, the city or village one-quarter and the state one-quarter of the cost. In Ohio, if the railroad company and the municipal authorities agree that the crossing may be abolished, not more than 35 per cent. of the cost is paid by the municipality and not less than 65 per cent. by the railroad company. This is certainly not burdensome on the municipality, especially when we remember that the railroad company, being a large taxpayer, eventually pays no mean proportion of the 35 per cent. charged to the municipality.

In the design for the work, if the railroad is put under the highway, there should be not less than 18 feet headroom and 2 feet for floor of bridge. In Ohio there is a statute obliging an obstruction over a railroad track to be at least 21 feet above the top of rail, but I think this should be amended so as to give the Railroad Commissioner some discretion in the matter. Out on the open road, where trains run fast, and in the days before the nearly universal use of air brakes had greatly diminished the brakeman's duties in running from one car to another to set the brake, it might have been proper to require such headroom; but in these days, and in cities, where there is slow movement and where the locomotives and cars are equipped with air brakes, it does not seem necessary in all cases; and in fact other cities are adopting less headroom, and the Erie Railroad has been running for years in this city under bridges of very much less headroom, properly protected, without accident. I think the headroom should not be less than 18 feet, however; first, to allow for the future probable increase in height of locomotives and cars, which are constantly growing higher and higher, and also to allow a brakeman, if he is on top of a car, to sit down without being struck. If it were impressed on him that he could not stand, but might sit down, on going through a city, the liability to accident would be much reduced.

If the highway is put under the railroad there should be at least 13 feet headroom allowed, with 2 feet for floor of bridge at

highways where there is or may be an electric railroad, and 12 feet, with 2 feet for floor of bridge, at highways where no electric railway is likely to be built. This will not allow the use of a double-decked electric car, but I think it is not unreasonable to make this restriction. In fact, it must be remembered that the placing of the highway under the railroad immediately restricts materially the height of the vehicle and its load that can pass under the bridge, a restriction that, except for the trolley wires, which I hope are but temporary, is not encountered in any other part of the highway. The gorgeous band-wagon of the circus, for instance, or the floats of an industrial parade will have to take another route, whereas the railroad equipment is restricted just as much by other things, such as the heights of the top bracing on bridges or the cross-section of the tunnels, etc. This is one of the strong arguments in favor of placing the highway above the railroad.

The width of the highway should not be restricted unless under exceptional circumstances. It is true that London Bridge, with its enormous traffic, is but 56 feet wide, and that Chestnut Street Bridge, in Philadelphia, is but 40 feet wide; yet room seems to be necessary in this bustling life of ours, and the people are entitled to it. The grades on the highway approaches should be not more than 5 per cent. This is the grade used in Chicago, and many cities have steeper natural ones; certainly Cleveland has. I mention Chestnut Street Bridge because it is on one of the main thoroughfares between populations nearly twice as large as in Cleveland, and carries two street railroad tracks.

Nor should the width of the railroad be curtailed. It is hard to foresee what conditions may arise, and allowance must be made for future growth. If a highway becomes congested there are other highways, but to obtain other railroad tracks is another matter; always expensive, often impossible. The grades on the railroad should not be changed to make them a burden at the time or in the event of any possible future improvement to the railroad property, and for this reason great care must be taken in raising the elevation of the railroad tracks or in increasing their grade, as such change might involve a very serious burden on the property. There may be very little, if any, reserve power in a locomotive. It is usually loaded to its capacity; whereas, in the individual and electric car, within certain limits, there is ample reserve power, and the same is true of most horses. The railroad is an essential and admirable instrument in the growth and development of a city. It is a tool not to be abused and knocked about, but, like all other good tools, to be handled somewhat affectionately; to be kept always neat and clean and in thorough working order.

Other things being equal, it is certainly lighter, pleasanter, in every way better, to raise the highway. This may or may not involve the depression of the railroad tracks. If the tracks can remain as they are, well and good. In that case we have only to see that the structure and its supports are so constructed that they shall not interfere with the railroad and its operation; and, although the railroad authorities are seemingly actuated by selfish motives, it is pretty safe to conclude that they are fairly good guides to follow in these and in similar cases. If the tracks must be raised or lowered in order to avoid steep approaches or excessive property damage, it may be wise to lower them, the depth depending on circumstances. Through the residence district of a great city it may be well to lower the tracks the full distance required. An elevated track is an eyesore, noisy, extremely ugly and altogether horrid. Through the manufacturing districts of the same city it is better to elevate them, other things being equal; or, at most, to depress them but a few feet, so that existing manufactories can meet the changed conditions without excessive expenditure, and that adjoining unimproved property owners may not be deprived of the use of their property for the best purpose to which it can be put, as might be the case if the railroad tracks were depressed the full distance required. It is also true that, especially with railroad tracks, it is much easier and cheaper to raise them than to depress them.

The difficulties incident to the location of sewers, water mains, etc., in the depression of the tracks have no terrors for the engineer who is familiar with the work done by the cable car company in New York city, or with that proposed to be done by the Rapid Transit Company.

The question of damage to abutting property on the highway is always comparatively an important one where conditions are changed ever so slightly, and is always very thoroughly considered in cases of this kind; but it should not be given undue importance. Granted an equitable division, the cost is a secondary consideration, as the work is for all time and should be done in the best manner. Then again, the damage is only the cost of changing the buildings and other improvements to meet the changed conditions. The value of the land itself is rarely changed, for that depends upon the ease of access to and from a more or less crowded thoroughfare. For instance, the most valuable land in the world is at the intersection of Fleet street and the Strand in London, because of the crowds passing it. The corner of Broad and Wall streets, in New York, is possibly equally valuable, and especially in a raised highway this condition is not changed. What, then, is the damage to

the improvements? If, for instance, all the buildings at the corner of Euclid and Willson avenues and 200 feet each side were wiped out by fire in a night, the most sensational report would not put the loss on the buildings alone at any enormous figure. The insurance companies would certainly pay much less, and I do not doubt that the owners' sworn estimates of their value made to the tax assessor would show a very much further reduction from the amount the insurance companies would be called upon to pay; and again, the buildings in the aggregate would be damaged much less than half their value. Looked at in this way, the damage is reduced to a less formidable proposition. The trouble consists in arousing the antagonism of the owners themselves, who generally, and by the very nature of things, are men of influence and standing, and of much more power in the community than is the intangible stockholder of the railroad company, for instance; so that it is easy for them to obtain excessive judgments, especially when municipalities and corporations are to pay them. The process of awarding damages is human, therefore fallible. It might be better to appoint one or a few good men as commissioners to award them in place of the ordinary jury, as has been done in New York; but this may seem arbitrary to many accustomed to the old way.

In the actual performance of the work, that party who is in position to do any part of it best and most cheaply should do it. The municipality should settle the damages with abutting owners; and, as it can borrow money more cheaply than can the railroad companies, it might, if desired, lend its credit to the latter under well-considered conditions. The railroad companies might build part or the whole of the structure. The general principles being agreed upon, the details can easily be arranged.

As far as the maintenance is concerned, each party should maintain that part worn or used by it exclusively, and those parts where failure would render it liable in damages to others; where several parties use the same part, or where several would be liable, the expense should be divided proportionately.

DISCUSSION.

H. C. THOMPSON.—In the question of the elimination of grade crossings of steam railroads there are three parties concerned,—the city, the railroad and the manufacturers located on the line of the railroad,—each of whom have interests which should be carefully considered; the object being the harmonizing of these interests so that the expense of the improvement shall be equitably distributed.

The necessity of the improvement cannot be questioned. It grows every day, as the population and business of the city increase, and the longer it is postponed the greater will be the cost.

The crossings should be made above or below the grade of the railroad, as the conditions of each particular crossing are presented. The full width of the street should be maintained in all cases. The city has a moral right to demand this improvement, and all interested should be obliged to acquiesce in whatever arrangement is finally agreed upon.

The railroads were on the ground first, the city having grown to them and around them, thereby creating the demand for a change in the crossings.

It is fair to presume that when the railroads were built the construction followed the lines of economy with respect to the utility of the line as compared with the ground on which it was built, although possibly better results could have been attained at an increased outlay of first cost. Assuming this to be true, the expenditure of an additional sum would not destroy the present effectiveness or lessen the economy in operation as compared with what now obtains. This expenditure would be necessary to make the present gradients conform to the improved crossings, involving structures above, below and at the grade of the present roadbeds. The railroads have contributed to the growth of the city, and at the same time have profited by this growth, which has enhanced the value of their own property as well as that in the immediate vicinity.

The interests of the manufacturers and those of the railroad are to a great extent mutual, the manufacturer depending on the railroad for transportation, and the railroad deriving a great portion of its profit from the manufacturer. The manufacturer on the line of the railroad would have to conform to the new gradient of the railroad, because the conditions which obtain are more elastic, so far as he is concerned, than with the railroad, where the object is to preserve the present effectiveness with economy in operation.

It is to the interest of the city to encourage the manufacturer, because he contributes to the growth of the city; and, incidentally, the railroad enables the city to give this encouragement. The obvious conclusion is that all the interests involved are closely allied, and to a great extent mutual.

It would be premature at this time to say definitely how the expense should be divided. This could be arrived at intelligently only after a fair consideration of all the details of a perfected plan of operation, and, to the mind of the writer, the proper way to arrive at this end would be through a tribunal created expressly for this work, in which all the interests should be fairly represented. This tribunal should be clothed with power to determine on all questions which may arise, and should be composed of men skilled in this line of work, and able to give their time to a full consideration of the whole subject.

Association of Engineering Societies.

Vol. XXIII. JULY, 1899. No. 1.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, June 2, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Upon ballot, the following gentlemen were declared duly elected to associate membership: Alexander G. McAdie, U. S. Weather Bureau, and Erland Gjessing, of San Francisco.

The following applications were made and referred to the Executive Committee:

For members—Henry S. Dutton, architect, of San Francisco; proposed by G. W. Percy, H. C. Behr and Edw. F. Haas. Franklin C. Prindle, civil engineer, U. S. Navy, San Francisco; proposed by Otto von Geldern, G. W. Percy and Marsden Manson. Colonel S. M. Mansfield, corps of engineers, U. S. A.; proposed by Otto von Geldern, A. Ballantyne and C. E. Grunsky. Major W. H. Heuer, corps of engineers, U. S. A.; proposed by Hubert Vischer, A. Ballantyne and Otto von Geldern. Major C. E. L. B. Davis, corps of engineers, U. S. A.; proposed by Otto von Geldern, Hubert Vischer and A. Ballantyne. For associate—Geo. P. Wetmore, concrete builder, San Francisco; proposed by G. W. Percy, H. Barth and Otto von Geldern.

Mr. A. G. McAdie addressed the members on the subject of "Storm Structure," presenting an interesting description of the work and methods of the U. S. Weather Bureau, which was illustrated by fine lantern slides made for the purpose of the lecture.

The President expressed the thanks of the Society to Mr. McAdie and adjourned the meeting until the first Friday in August.

Otto von Geldern, *Secretary.*

Montana Society of Engineers.

A special meeting was held in the art room of the Butte Public Library, Butte, Montana, on July 8, 1899.

Meeting called to order by President Eugene Carroll at 8.30 p.m.; Mr. R. A. McArthur acting as Secretary *pro tem.*

Nine members and three visitors were present. The minutes of the preceding meeting in Helena were read and approved.

Messrs. John C. Patterson and Frederic J. Taylor were appointed a committee to prepare a memoir in honor of the late Henry C. Relf. It was found that less than one-half of the members had voted upon the amendment to the Constitution. Consequently the letter ballots were not opened and canvassed, but deferred to the next meeting.

Adjourned. A. S. Hovey, *Secretary.*

Association of Engineering Societies.

Vol. XXIII. **AUGUST, 1899.** No. 2.

PROCEEDINGS.

Detroit Engineering Society.

The 40th regular meeting of the Society was held at the Hotel Ste. Claire, Friday, May 26, 1899; President W. J. Keep presiding.

The paper of the evening, "Deposits in the Pipe System of Detroit Water Works," was read by Mr. C. W. Hubbell, Civil Engineer to the Board of Water Commissioners, and discussed by several of the members present.

Adjourned. Henry Goldmark, *Secretary.*

The 41st regular meeting of the Society was held at the Hotel Ste. Claire, Friday, June 23, 1899.

Twenty-one members and guests were present. In the absence of all the officers of the Society, Prof. C. E. Greene was elected chairman of the meeting, and Mr. S. H. Woodard Secretary.

The name of John H. Galway was proposed for membership.

The paper of the evening was read by Alexander B. Raymond, upon "House Drainage," and discussed by Prof. Greene and Mr. Hubbell.

Adjourned.

Engineers' Club of Cincinnati.

107th Regular Meeting, Cincinnati, O., June 15, 1899.—Dinner was served at 6.15 p.m.; eighteen members and three visitors present.

The regular meeting was called to order at 7.10 p.m.; with President Hazard in the chair.

Minutes of the meeting of May 16 were read and approved.

The Secretary read a letter from Mr. W. B. Ruggles, dated Matanzas, Cuba, and addressed to Mr. R. L. Read, with which he sent a gavel for presentation to the club. The head of the gavel is made from wood taken from the Santa Christina Barracks at Matanzas, built some fifty years or more ago. On motion, the Secretary was directed to send to Mr. Ruggles the thanks of the Club for his kindly remembrance.

Dr. Thomas Evans, instructor in technical chemistry at the University of Cincinnati, read a paper on "Fuel Gas," devoted principally to discussions and descriptions of processes for the manufacture of fuel gas for use in metallurgical works.

Mr. L. E. Bogen read a paper under the title of "The Testing of Iron and Steel," in which he reviewed what has been accomplished in determining the quality of these metals by microscopical inspection.

Both papers were quite freely discussed.

Adjourned. J. F. Wilson, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, September 1, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

The following names were declared elected upon count of ballot:

Members—Paul W. Prutzman, chemist, San Francisco; Thos. Morrin, mechanical engineer, San Francisco. Associate member—Richard Keatinge, concrete builder, San Francisco.

A letter was read from the Southern Pacific Railroad Company, stating terms on which an excursion to Palo Alto could be conducted. It was referred to the Board of Directors, with power to act.

Thereupon, Mr. G. A. Wright, architect, read a paper on the subject of "The Quantity System of Inviting Bids from Contractors, and its Application to Engineering and Architectural Practice," a discussion of which was participated in by many of the members present.

Adjourned. C. E. Grunsky, *Acting Secretary.*

Association of Engineering Societies.

Vol. XXIII. **SEPTEMBER, 1899.** No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 20, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President C. Frank Allen in the chair. Sixty-seven members and visitors present.

The Secretary being absent, on motion of Professor Swain, Mr. E. W. Howe was appointed Secretary *pro tem.*

The record of the last meeting was read and approved.

The President appointed Mr. R. A. Hale a committee to distribute, receive and count the votes for new members. Messrs. Charles B. Breed, John H. Emigh and Orville J. Whitney were elected members of the Society, forty-two ballots having been cast for all the candidates.

Prof. George F. Swain, for the Committee on the Amendment of the By-laws, read the following report:

The committee appointed to draft the proposed change in Section 5 of the By-laws begs leave to recommend that paragraph 2 of Section 5 be amended so that it shall read as follows: "Of the candidates for any office, the one having the largest number of legal votes by the letter ballot shall be declared elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied, a majority of the votes cast being required to elect."

George F. Swain,
Alexis H. French,
Frederic P. Stearns, } *Committee.*

On motion of Fred. Brooks, the report of the committee was accepted and the committee discharged. Mr. Brooks moved that the amendment be adopted, and it was voted that the amendment be printed in the notice of the next meeting. Action on the adoption of the amendment was postponed until the next meeting, as required by the By-laws.

Mr. H. A. Carson, for the committee, consisting of himself and Mr. Otis F. Clapp, read a memoir of Mr. Charles H. Swan.

The following letter was read from Mr. Charles A. Pearson, member of the Society:

Boston, Mass., September 20, 1899.

Prof. C. Frank Allen, President of the Boston Society of Civil Engineers:

Dear Sir:—It gives me pleasure in presenting through you to the Boston Society of Civil Engineers a portrait of the late Thomas Doane.

That Mr. Doane's personal qualities were appreciated by the Society is fully attested by the number of years which he served as its President, and also by his membership on important committees relating to the welfare of the Society.

In presenting this portrait I feel that it is but a fitting memorial in remembrance of one with whom I was intimately associated for thirty years.

His example was one worthy of following. His presence commanded respect, his opinions attention. His daily life was one of Christian love, purity and charity.

Yours very respectfully,

CHARLES A. PEARSON.

The portrait was accepted on behalf of the Society by the President with a few appropriate remarks. On motion of Prof. G. F. Swain, seconded by Mr. H. A. Carson, the thanks of the Society were voted to Mr. C. A. Pearson for the portrait of Mr. Doane.

President Allen then read a memoir of Mr. Doane, prepared by a committee consisting of Messrs. Desmond FitzGerald, C. Frank Allen and C. A. Pearson.

On motion of Mr. C. W. Sherman, it was voted that the Society tender its thanks to the Pennsylvania Steel Company, contractors for the Fort Point Channel Bridge, and to the Lowney Chocolate Company, for courtesies extended on the occasion of the excursion of July 19, and to Benj. W. Wells, Superintendent of Streets, Boston, the New England Sanitary Product Company and the Metropolitan Sewerage Commission, for courtesies extended on the occasion of the excursion of August 23.

Mr. H. A. Carson, Past-President of the Society, then gave a very interesting account of his recent visit to Egypt and Europe, and exhibited a large number of lantern views.

Adjourned at 10 P.M. E. W. HOWE, *Secretary pro tem.*

Charles Herbert Swan.—A Memoir.

BY HOWARD A. CARSON AND OTIS F. CLAPP, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, September 20, 1899.]

CHARLES HERBERT SWAN, who was a member of this Society for about seventeen years before his death, was born in Boston, August 17, 1842. Several of his immediate ancestors were prominent in this community. One of his great-grandfathers was a major in the Revolutionary War. On his father's side, Charles was related to the Tufts family, after whom Tufts College was named. Deacon James Loring, his grandfather on his mother's side, was founder of *The Watchman,* the well-known Baptist paper. His father, James G. Swan, formerly of Medford, is still living, in the State of Washington. His mother was Matilda Loring Swan, of Boston, who died in 1863. Charles was the older of two children. Miss Ellen M. Swan, his sister, lives in Boston.

In his youth he lived on Chapman place, near School street. He attended the Boston public schools, including the Brimmer and the Latin School, and, in March, 1859, entered the Lawrence Scientific School, from

which he was graduated in 1861. One of his classmates and friends at the Lawrence Scientific School, Roberdeau Buchanan, now an assistant in the Nautical Almanac Office, Washington, gives some incidents in regard to that portion of his life. Young Swan was remarkably quick mentally, and seldom failed to go through the demonstrations at the blackboard. The students were not marked and graded for their recitations, but he stood high in his studies. One day, after Professor Eustis had left the hall, Buchanan and Swan were engaged in their drawings, when the latter was overheard whistling the overture to "The Messiah," and later these friends and others often met to practice classical and other music, Swan playing the flute. Soon after taking their degrees of Bachelor of Science they both entered the office of C. L. Stevenson, civil engineer. The Civil War was then just beginning, and, as they had imbibed a number of military ideas from Professor Eustis, they determined to study fortifications together, and went through the course which was then pursued at West Point, making the customary drawings.

Later Mr. Stevenson was chief engineer on the construction of the Charlestown Water Works, and young Swan was engaged by him during its whole three years' progress. After the preliminary surveys were finished, he was assigned to the city division, in charge of laying the street mains. At the completion of the work a marble slab was erected at the pumping station in commemoration, and on this slab his name may be found among those of the other engineers, the commissioners, the Mayor, etc.

At a later time he was one of the engineers connected with the construction of the Salem Water Works, and he remained there until the fall of 1869, the last year of the time as acting chief engineer. He went from there to Providence, R. I., where he was one of the assistant engineers to J. Herbert Shedd, on water and sewerage works. While in Providence he was the first engineer to work out an abbreviation of the Kutter formula applicable to sewerage work, constructing a valuable set of sewer diagrams based upon that formula. He was specially connected with the numerous investigations entered into in the development of the plans for the water works and sewerage systems, and his services were valuable and highly appreciated.

He remained in Providence until 1881, except that he spent a part of 1874 and 1875 in Europe on account of his health. In 1880 he had serious eye trouble and was obliged to discontinue work for three years. He moved to Boston in 1881.

In 1884 he went to Europe with Samuel M. Gray, City Engineer of Providence, to study the sewerage systems of various European cities, and prepared the historical portion of the resulting report.

In 1886 he was employed, for about six or eight months, by Rudolph Hering, then Chief Engineer of the Chicago Water Supply and Drainage Commission, as a special assistant, to work out the problem of disposing of the sewage of the city of Chicago by filtration on land, and to estimate the cost thereof. Between the fall of 1887 and the spring of 1888 he was engaged, in making a study, for the Water Supply and Sewerage Committee of the Massachusetts State Board of Health, of the scheme of disposal of the sewage of the North Metropolitan Sewerage District by chemical precipitation.

He was teacher, for one term, at the Lawrence Scientific School during the absence of Professor Chaplin, in the spring of 1889, giving instruction in the strength of materials, in hydraulics, and in water supply and sanitary engineering.

In 1889 he was appointed one of the assistant engineers on the Metropolitan Sewerage System, and continued to be more or less actively connected with that work until the time of his death. He was specially engaged, in this connection, with all of the laborious and important investigations and studies as to the flow of sewage in the siphons and all other portions of the system and in investigations as to the stability of chimneys and various other structures.

From October, 1894, to September, 1897, he was an assistant engineer on the Boston subway, and made numerous studies for changes in sewers, pipes, etc. During a portion of this period he was also employed on the Metropolitan Sewerage System.

In the winter of 1897-1898 he made a report on a projected joint system of sewerage for Salem and Peabody. The question at issue was chiefly the apportionment of the cost between the two. Mr. Swan was employed by Salem.

From 1898 to 1899 he was again devoting his whole time to the Metropolitan Sewerage work, where he had charge of the special hydraulic studies and the preparation of the text of the engineering portion of the report for the high level gravity sewer for the relief of the Charles and Neponset River Valleys.

He became a member of the American Society of Civil Engineers in 1870, and of the Boston Society of Civil Engineers in 1882.

Soon after his twenty-first year he was received into the First Baptist Church of Boston. In 1872 he and Mrs. Swan joined the Roger Williams Free Baptist Church, of Providence. Not long after his removal to Boston, in 1881, he was received into the First Free Baptist Church, of which he was a member until his death. At the time of his death he was the President of the legal society managing the property of this church.

Those for whom and with whom he worked testify to his ability, his careful industry and the marked excellence of his work. He was very fond of books and had a good collection of his own, and he took great interest in systematically arranging and indexing them. His love of music and his skill in playing the flute have already been mentioned. This taste and skill continued through life and were the means of giving pleasure to many of his friends. During his later years he became much interested in photography, and was skilled in taking and developing photographs and in making transparencies. He was quiet and unobtrusive, but among those who knew him well he was an exceedingly entertaining and pleasant companion. The writers, and others who knew him intimately for years, cannot recall ever hearing him speak an uncharitable or unkind word.

June 30, 1870, he married Miss Carrie Cheney, a daughter of President O. B. Cheney, of Bates College, Lewiston, Maine. His widow and four sons survive him, the youngest being nineteen years of age. His domestic life was an ideal one. He was a loving husband and father.

Though not as robust as many men, and though at times suffering somewhat from a weakness of the eyes, he generally enjoyed good health, and there was every prospect that he would live and work for many years to come. On Tuesday, April 12, he visited the Metropolitan Sewerage office for the last time. The next day he was suffering somewhat from tonsillitis. On Sunday morning, April 16, he was found to be afflicted with malignant diphtheria. After some hours of apparent unconsciousness he died on Monday morning, April 17, 1899, aged nearly fifty-seven years.

Engineers' Club of St. Louis.

SEPTEMBER 20, 1899.—Meeting was called to order at 8.20 P.M.; President Colby presiding. Sixteen members and four visitors were present. The minutes of the 492d meeting were read and approved. The minutes of the 277th and 278th meetings of the Executive Committee were read. The application of Mr. O. J. Barwick having been recommended by the Executive Committee, he was balloted for and declared elected. The names of Messrs. E. B. Fay, E. A. Cordes, F. D. Beardslee, O. M. C. Bilhartz, Frank Ringer and W. J. Fogarty were proposed for membership.

The paper of the evening, entitled "Discipline," by Mr. Willard Beahan, was then read by the Secretary in the absence of the author.

In this paper the relations that should be maintained between employer or superintendent and employes were discussed, being divided under three heads: first, the right of the men to be heard; second, their right treatment; third, wages.

Under the first it was maintained that a hearing should always be given the men, whether they came as individuals, committee or society, and that by so doing the answer, whether acceding to their requests or not, if given with the reasons for it, would usually be gracefully accepted.

Under the second head, the necessity of seeing that the men's comfort and well-being be carefully looked after was set forth. Also that usually the head man should fare no better than the men if it is desired that they remain contented.

The question of wages was next considered and the adoption of a sliding scale of payment advocated, as in this way the most valuable men are gradually enabled to earn more and will thus be kept for long periods of time, to the benefit of their employers.

Mr. Beahan also went into the question of strikes, treating of their prevention and treatment after occurring.

The discussion following was participated in by Messrs. Bryan, Fish, Borden, Bouton, Colby and Von Ornum.

There being no further business, the meeting adjourned.

E. R. FISH, *Secretary.*

Montana Society of Engineers.

A MEETING of the Society was held in the Butte Public Library, Butte, Montana, on September 9, 1899. Meeting called to order at 8.30 P.M.; Mr. Francis W. Blackford in the chair, Mr. R. A. McArthur Secretary *pro tem.*

The applications for membership of Richard R. Vail and Albert Koberle were read and referred to the Trustees.

A vote of thanks was tendered Senator T. H. Carter for securing for the Society the Presidential messages and papers, consisting of a number of nicely bound volumes, containing all the messages of the Presidents.

Messrs. Page and Flood were appointed tellers to canvass the ballots on the proposed change of constitution, changing the headquarters of the Society from Helena to Butte. The vote was: Yes 56, no 6. Total vote cast 62. Whereupon the chair declared the amendment carried. Thus Butte becomes the headquarters of the Society.

A committee consisting of Messrs. Aug. Christian, John Gillie and F. J. Smith was appointed to nominate officers for the ensuing year.

Adjourned. A. S. HOVEY, *Secretary.*

Engineers' Club of Cincinnati.

108TH REGULAR MEETING, CINCINNATI, OHIO, SEPTEMBER 21, 1899.—Dinner was served at 6.20 P.M. Eighteen members and three visitors.

The regular meeting was called to order at 7.30; Vice-President Punshon in the chair.

Minutes of the meeting of June 15 were read and approved.

Application for active membership was received from Mr. Frank L. Fales, Assistant Engineer, Chief Engineer's Office, Board of Trustees, Commissioners of Water Works.

Mr. W. M. Venable, who was announced to read a paper on "Camp Engineering of Two Great Army Camps," described the work of the engineer corps, with which he was connected during the late war with Spain, at Camp Wikoff, at Montauk Point, N. Y., and at Camp Columbia, at Mariano, Cuba, in the establishment of these camps and in improving the sanitary conditions at them, more especially the former, which necessitated an immense amount of labor on account of the large number of troops to be provided for in the very short time allowed.

He exhibited several maps of the camps and a large number of photographs specially pertaining to the work, and others of points of interest taken during the campaign.

On motion, adjourned. J. F. WILSON, *Secretary.*

Association of Engineering Societies.

Vol. XXIII. **October, 1899.** No. 4.

PROCEEDINGS.

Engineers' Club of St. Louis.

494th Meeting, October 4, 1899.—The meeting was called to order at 8 p.m.; President Colby presiding. Sixteen members and three visitors were present. Messrs. Fogarty, Fay, Bilhartz, Ringer, Cordes and Beardslee, having been recommended for membership, were balloted for and all declared elected.

The paper of the evening, entitled "The Development of the Automatic Machine for Metal Working," was then read by Mr. H. S. Wilson. The probable incidents that led to the invention of the earliest and crudest form of machinery were given, together with short descriptions of the machines. The author then went on to give brief descriptions of old but more modern forms of automatic machines, showing how automatic machines of yesterday become the semi-automatic or non-automatic of to-day by reason of constant improvement.

The machines used for automatically making a large variety of articles were briefly described, and some of the wonderful results achieved with them noted.

Mr. McFarland exhibited some samples of automatic machine work.

There being no further business, the meeting adjourned.

E. R. Fish, *Secretary.*

495th Meeting, October 18, 1899.—The meeting was called to order at 8.15 p.m.; President Colby presiding. Thirty-two members and twelve visitors were present. The minutes of the 494th meeting were read and approved. The name of Mr. Jos. Boyer was proposed for membership. The paper of the evening, on "The Design and Construction of a Modern Central Station," was then read by Mr. H. H. Humphrey. A brief *résumé* of the legislation creating the underground conduit system for electric wires was given, and also the conditions influencing the organization of the Imperial Electric Light, Heat and Power Company. The conditions governing the design of the plant were fully entered into and afterward a general description given of the various parts of the equipment, both mechanical and electrical, and also of the conduit system and method of distribution. The paper was illustrated by lantern slides shown as referred to in paper.

The discussion following was participated in by Messrs. Wilson, Holman, Bryan, Reeves, Borden and Kinealy. There being no further business, the meeting adjourned.

E. R. Fish, *Secretary.*

Technical Society of the Pacific Coast.

Regular Meeting, October 6, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Mr. Stephen E. Kieffer, civil engineer, Sacramento, was elected to membership by regular ballot.

A letter was read from the Southern Pacific Company, stating rates at which a car may be had for the purpose of a Society excursion to Palo Alto and Greystone Quarry.

It was ordered that the Secretary circulate notices, requesting members to notify the Society of their willingness to attend this outing to visit the Memorial Arch now building on the Stanford University grounds, and to inspect the neighboring quarries; and that the date of the excursion be set for Saturday, October 14. (This date was subsequently postponed to October 21, and, on account of the inclemency of the weather, again postponed until October 28.)

Mr. Max Junghaendel, a visiting architect, discussed the plans and designs for the State University buildings, adopted by the late jury in the Phœbe Hearst competition, and criticized at length the various features of a design so vast and costly, which could not be realized under any of the ordinary conditions of time and adequate appropriations. This criticism was discussed by a number of visiting architects and engineers.

It was moved that the President and Secretary confer with Mr. J. Reinstein, and to ask of this gentleman the courtesy of permitting Mr. Junghaendel to take photographs of the various plans and drawings submitted to the jury by competing architects. Carried.

Adjourned. Otto von Geldern, *Secretary.*

Detroit Engineering Society.

The 43d regular meeting of the Detroit Engineering Society was held at the Hotel St. Claire, October 27, President Keep presiding. Minutes of the last meeting read and approved.

Mr. E. S. Reid was elected a member of the Society, and the name of Mr. F. A. Little was proposed for membership and referred to the Executive Committee. The paper of the evening was read by Mr. David Molitor, and was illustrated by blackboard sketches. The paper was discussed by Messrs. Williams and Dow. A vote of thanks was extended to the speaker of the evening. Attendance twenty-six. Meeting adjourned at 10.45 p.m.

T. H. Hinchman, Jr., *Secretary.*

Engineers' Club of Cincinnati.

109th Regular Meeting, Cincinnati, Ohio, October 19, 1899.—Dinner was served at 6.15 p.m. Fourteen members and one visitor present.

The regular meeting was called to order at 7.35 p.m.; Vice-President Punshon in the chair.

Minutes of the meeting of September 21 were read and approved.

On ballot being taken, Mr. Frank L. Fales was elected to active membership.

Mr. David Goldfogle read the paper for the evening, on "Some Details of Two Sewer Tunnels." The first part of the paper comprised a description of the construction of a brick sewer 11 feet in diameter, about 300 feet long, which was tunneled through the embankment supporting the Miami Canal at a point a short distance south of the Mitchell avenue aqueduct. At this point there existed an old stone culvert, semicircular in shape, from 5½ to 6 feet in height and about 12 feet in width at the bottom, which had been built at the time of the construction of the canal. This culvert had for its foundation a layer of hewn oak logs, about 10" x 12", laid close together and extending a short distance beyond the sides of the culvert. This old culvert was in very bad condition, the mortar having fallen from the joints, leaving large holes in the sides and top, necessitating great care in the construction of the new sewer, which was so located with reference to the old culvert that its bottom was about 8½ feet below the top of the old timber floor at the west end and about 5½ feet at the east end.

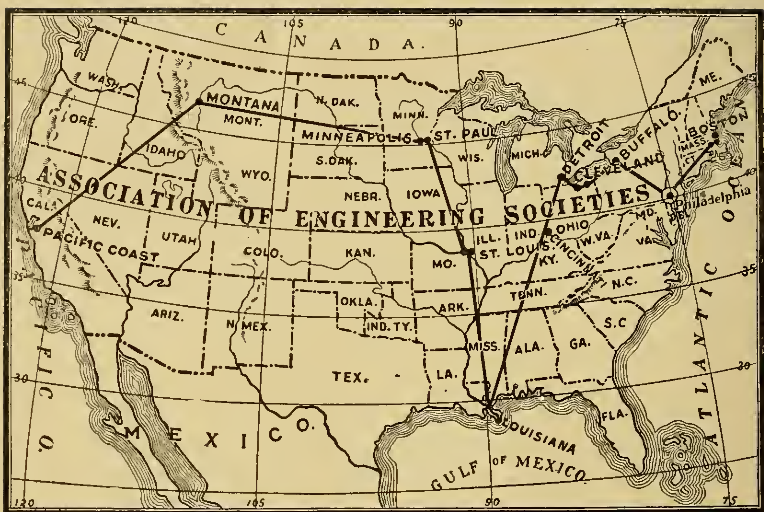
A wooden flume was constructed on top of the timber floor to carry the creek water during the construction of the lower half of the sewer. When this lower half had been completed for the entire length up to the timber floor, the old culvert being supported in the meantime by means of wooden struts and beams as the work progressed, the water was turned into it, the timber floor was cut away in sections and the upper half of the circular sewer built inside the old culvert, beginning at the middle and progressing each way. The space between the top of the new sewer and the inside of the old culvert was filled in solidly with brickwork. The total cost of the work to the contractor was about $22 per lineal foot of sewer.

The second part of the paper was devoted to a description of the method of constructing a tunnel for a 16-inch cast iron pipe sewer to replace a damaged 15-inch pipe sewer. The material encountered was blue shale and rock, and required blasting for its removal. The material was conveyed to the surface through shafts, in some of which brick manholes were built, the others being used simply for the purpose of facilitating construction and were filled up after the work was completed. The tunnel, after the pipe was laid, was filled with concrete to the center line of the pipe and the excavated material placed back on top of the pipe, completely filling the tunnel.

Illustrative maps and plans accompanied the paper, and after the reading of same a general discussion followed.

Mr. Elzner described briefly the septic system of sewage disposal.

Adjourned. J. F. Wilson, *Secretary.*


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
CINCINNATI
ST. LOUIS
LOUISIANA
PACIFIC COAST
MEXICO.
GULF OF MEXICO
PACIFIC O.
ATLANTIC O.
WASH.
ORE.
IDAHO
MONT.
N. DAK.
MINN.
S. DAK.
WIS.
MICH.
WYO.
NEBR.
IOWA
CAL.
NEV.
UTAH
COLO.
KAN.
MO.
ILL.
IND.
OHIO
W.VA.
MD.
VA.
KY.
N.C.
TENN.
S.C.
ARIZ.
N. MEX.
OKLA.
IND. TY.
ARK.
MISS.
ALA.
GA.
TEX.
LA.
FLA.
ME.
MASS.

Association of Engineering Societies.

Vol. XXIII. **NOVEMBER, 1899.** No. 5.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, November 3, 1899.—Called to order at 8.30 p.m. by President Percy. The minutes of the last regular meeting were read and approved.

Mr. George Johnston, mechanical engineer, of San Francisco, applied for membership; proposed by G. W. Dickie, John Richards and G. W. Percy. The application was referred to the Board of Directors.

Mr. John Richards, Past-President, addressed the Society on the subject of "Patents and Monopoly," which was discussed at length by members present.

It was suggested by the author of the paper that a committee be appointed to inquire into and note the method of procedure followed by the U. S. Patent Office in the matter of determining the merits of a claim and granting the patent privileges. Also to compare these methods with those in vogue in foreign countries, and to report the results of these studies to the Society.

Mr. Dickie moved that a committee of three be appointed by the chair, and that the President be granted until the December meeting to select from the membership a suitable committee for this purpose. Carried.

The meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Engineers' Society of Western New York.

The Engineers' Society of Western New York was delightfully entertained November 6, 1899, by a lecture, entitled "An Excursion to Egypt and Europe," delivered by Mr. Howard A. Carson, member Am. Soc. C. E., and a prominent engineer of Boston. The lecture was replete with interesting information, pleasingly illustrated by stereopticon views.

Boston Society of Civil Engineers.

Boston, Mass., October 18, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m.; President C. Frank Allen in the chair. Fifty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. George Corrie Bartram, Frank Harrie Carter, William Lewis Clark and William Vaughan Polleys were elected members of the Society, twenty-five votes having been cast, all in the affirmative.

The amendment to By-law 5, which was reported at the last meeting, and which had been printed in the notice of this meeting, was then taken up. On motion of Mr. E. W. Howe, duly seconded, the amendment was adopted, twenty-three voting in the affirmative and one in the negative. As amended the second paragraph of By-law 5 reads as follows:

"Of the candidates for any office, the one having the largest number of legal votes by letter ballot shall be elected. Should there be a failure to elect any officer on account of a tie, the meeting shall proceed to elect such officer by ballot from among the candidates so tied; a majority of the votes cast being required to elect."

The President announced the deaths of three members of the Society. Sumner Hollingsworth died June 26, 1899; John H. Blake died July 5, 1899, and Samuel Nott died October 1, 1899. On motion of Mr. L. F. Rice, the President was requested to appoint committees to prepare memoirs. The following committees have been named by the President:

On Memoir of Mr. Hollingsworth, Messrs. J. R. Freeman and Chas. T. Main; on Memoir of Mr. Blake, Messrs. Fred. Brooks and Wm. B. Fuller, and on Memoir of Mr. Nott, Messrs. L. B. Bidwell and Edward Sawyer.

Mr. Walter B. Snow was then introduced and read an exceedingly interesting and valuable paper, entitled "Mechanical Draft for Steam Boilers." The paper was profusely illustrated with lantern views.

At the conclusion of the reading of the paper, on motion of Mr. F. P. Stearns, the thanks of the Society were voted to Mr. Snow.

Adjourned. S. EVERETT TINKHAM, *Secretary.*

Engineers' Club of St. Louis.

497TH MEETING, NOVEMBER 15, 1899.—Meeting was called to order at 8.20 P.M.; President Colby presiding. Twenty-three members and six visitors were present. The minutes of the 496th meeting were read and approved. The minutes of the 281st meeting of the Executive Committee were read. It was moved and seconded, and the motion carried, that a Nominating Committee, to report at the following meeting, be elected. The result of the ballot was the election of Messrs. Russell, Holman, Bryan, Flad and Kinealy as a Nominating Committee.

The presentation of the 1898 Vol. of the Trans. of the Am. Inst. of Min. Engrs. by Col. E. D. Meier was announced, and a vote of thanks tendered the donor.

Prof. J. L. Van Ornum then read his paper on "The Volunteer Engineers in the War with Spain." A brief history of the formation of the engineer regiments was given and mention made of the numerous military duties and drills in which the regiments received thorough instruction. Besides the purely military features, the various engineering duties of these troops were explained, many of them being enumerated in detail. A short description of character of the actual work done by the Third Regiment while in Cuba was given. The paper was supplemented by a series of views, which were fully explained by the speaker.

The discussion was participated in by Messrs. Colby, Bryan, Kinealy, Nipher and Spencer. E. R. FISH, *Secretary.*

Montana Society of Engineers.

A MEETING of the Society was held in the art room of the Butte Public Library, Butte, Montana, on November 11, 1899.

Meeting called to order by President Eugene Carroll, at 8.30 P.M.; Mr. R. A. McArthur acting as Secretary *pro tem.*

The application for membership of Edmund B. McCormick, of Bozeman, Mont., was read and referred to the Trustees. The Secretary was instructed to send out letter ballots on the applications of R. R. Vail, Albert Koberle and Daniel J. McNally for membership.

Mr. Carroll, of the Transportation Committee, reported progress, satisfactory arrangements having been made with most of the railway companies for rates to the annual meeting, which occurs on the second Saturday in January. It was decided to hold the regular annual meeting of the Society at Bozeman, Mont.

The President appointed the Committee of Arrangements for the annual meeting as follows,—viz: Wm. H. Williams and Clayton H. Thorpe, both of Bozeman, and Frank L. Sizer, of Helena.

A letter from Vice-President M. S. Parker, relative to members from Utah, was referred to the annual meeting. The Secretary was instructed to call the December meeting for Butte, whereupon the Society adjourned.

A. S. HOVEY, *Secretary.*

Engineers' Club of Cincinnati.

110TH REGULAR MEETING. CINCINNATI, O., November 16, 1899.

Dinner was served at 6.20 P.M. Fourteen members present.

The regular meeting was called to order at 7.30 P.M., with Mr. Wm. C. Jewett in the chair.

Minutes of the meeting of October 19 were read and approved.

One application, for associate membership, was presented.

Mr. Alfred Petry read the paper for the evening, on "The Evansville Caisson." This caisson was built in 1896 and forms the bottom of the pump pit for the pumping station of the water works at Evansville, Ind. It is built of white oak and is circular in plan, with an outside batter, being a frustrum of a cone, 16 feet high, and with its top and bottom diameters 77 feet 6 inches and 80 feet 2 inches respectively. The roof is 8 feet thick, leaving a height of 8 feet for the working chamber.

The paper treated of the plan of construction of the caisson and the manner of sinking it to place, which was, for a part of the distance, by the use of compressed air, the apparatus for which was described in detail.

The caisson supports a stone masonry well, circular in shape, 53 feet inside diameter and 61 feet high, the wall of which is 12 feet 3 inches thick at the bottom, tapering to 4 feet at a point 17 feet from the top, and above that point continues the same thickness to the top. In this well are located the three pumping engines.

The paper was illustrated by a large sketch of the caisson and a number of photographic views at different stages of construction.

The reading of the paper was followed by a general discussion of the subject.

Adjourned. J. F. WILSON, *Secretary.*

Association of Engineering Societies.

Vol. XXIII. DECEMBER, 1899. No. 6.

PROCEEDINGS.

Engineers' Society of Western New York.

The fifth annual meeting of the Engineers' Society of Western New York was held in the rooms of the Ellicott Square Club on December 4, 1899.

Meeting called to order at 8 o'clock P.M.; Mr. Haven, chairman.

The following members and guests were present:

Messrs. March, Babcock, Tresise, Powell, Gorman, Dr. George Fell, Speyer, Pihl, Symons, Young, Mayor Diehl, Ricker, Haven, Eighmy, Buttolph, Knighton, Bassett, Houck, Kielland, Lewis, Clark, Rogers, Roberts, Fruauff, Rockwood, Diehl, C. F. Fell, Bardol, Knapp, Quintiss, Elliott, Wilson, Sornberger.

The minutes of the meeting of November 6th were read and approved.

The report of the Secretary, Mr. March, was read, received and filed.

REPORT OF THE SECRETARY.

Mr. President and Gentlemen:

Inasmuch as there were no annual reports presented a year ago, I wish to state briefly the work for 1898:

At the January meeting we were pleasingly entertained by Mr. E. C. Lufkin with a paper entitled "Pipe Lines."

February we were notified that the Society had been admitted as a member of the Association of Engineering Societies.

March, an instructive paper by Prof. R. C. Carpenter upon "Laboratory Experimental Work at Cornell University."

April, Major Symons presented the timely topic, "Coast Defenses and Fortifications," after which a light lunch was served at the rooms.

May, Mr. George W. Rafter gave an interesting paper on "The Run-Off of Niagara River."

June, report of the Reception Committee's work in welcoming the Convention of American Society of Mechanical Engineers, held at Niagara Falls.

Mr. W. S. Hunbert then delivered an exhaustive paper upon "Cement—Its Origin, History, Tests, Specifications, etc."

September, Mr. H. L. Noyes gave an interesting paper on "The Early History of Bridges."

October, Mr. T. Guilford Smith delivered a very comprehensive paper entitled "Important Works in Egypt."

The matter pertaining to the formation of a State Society looking toward effective legislation regarding the practice of engineering was laid on the table.

During October the American Society of Mining Engineers held one of its stated meetings in Buffalo, and our Society contributed largely to the entertainment of the convention, by various committees appointed to impart information, etc., and welcome the visitors, etc.

As there was no regular election of officers in December, 1898, the old officers retained offices during the year 1899.

At our regular March meeting we were favored by Mr. F. V. E. Bardol with an interesting talk upon "The Abatement of the Hamburg Canal Nuisance."

March 21, 1899, we held a special meeting to take action upon the preliminary plans of sites for the Pan-American Exposition, as the matter had been referred jointly to the Engineers' Society of Western New York and the Buffalo Chapter of Architects, by resolution of the directors of the Exposition Company.

At the special meeting held on June 15, the Secretary had the pleasure of reporting that nineteen new members had been elected.

The October meeting was full of enthusiasm and interest for the betterment of the Society.

At our November meeting we and lady friends were pleasingly entertained by Mr. Howard A. Carson, Mem. Am. Soc. C. E., a prominent engineer of Boston, who gave us a lecture entitled "An Excursion to Egypt and Europe," accompanied by stereopticon views.

This fifth annual meeting to-night will speak for itself, and I hope will live pleasantly in your memory for a long time.

The Society now numbers about fifty-four members.

Respectfully submitted,

H. T. MARCH,
Secretary for 1898 and 1899.

Report of the Treasurer, Mr. Bassett, was read, received and filed.

REPORT OF THE TREASURER—1898-1899.

Cash on hand, December 15, 1897		$366.72
Received from Secretary to November 24, 1899		598.70
Total		$965.42
Disbursements of sundry kinds	$746.53	
Permanent fund	80.00	
Balance in bank	138.89	
		$965.42

GEORGE B. BASSETT, *Treasurer.*

Messrs. Ricker and Roberts were appointed as tellers to canvass the vote of the Society.

After dinner the tellers reported that the following gentlemen were elected for the year 1900:

President—Mr. W. A. Haven.

Vice-Presidents—H. J. March, C. H. Tutton.

Secretary—George Diehl.

Treasurer—George R. Sikes.

Director—E. C. Lufkin.

Librarian—J. A. Knighton.

Mr. Haven declared the above-named officers duly elected for the ensuing year.

In the absence of Mr. Johnson, retiring President, Mr. Ricker, Past-President, delivered an address, in which he referred to certain features of the early history of the Society, and particularly to its entertainment of the American Society of Mechanical Engineers at Niagara Falls, an entertainment in which Mr. Johnson took an active part. Mr. Ricker emphasized the benefits which this Society can confer upon the engineers of Buffalo and of Western New York.

Mr. Haven, President-elect, expressed his appreciation of the honor conferred upon him by his election, and urged the importance of measures for making the members of the Society better acquainted with each other, of providing a more suitable place for meetings, and of having the proceedings published in the daily newspapers.

Hon. Conrad Diehl, Mayor of Buffalo, while claiming pre-eminence for his own profession of medicine, paid high tribute to the skill of engineers and to the importance of their work, calling attention to the bridge at Coblenz, the Mont Cenis Tunnel, the Niagara bridges, the Buffalo breakwater and the gorge road at Niagara as instances of such work.

Mr. Haven.—The Mayor has spoken to you about the nobleness of the medical profession, and that it is older than the engineering profession. During the coming year if I can get a draughtsman that knows how to make letters, I will give him something that was printed in 1645, entitled "The Description of a Complete Engineer," which I would like to have copied in pretty large letters and hung in the new rooms of the Society, showing that the engineering profession was known a good many years ago.

We would like to hear from some of the older engineers, and I will call upon Mr. Young to address us. (Applause.)

Mr. Young, referring to the Mayor's claims for the medical profession, called attention to the fact that the engineers were the pioneers of civilization, and that, while they could not rise superior to the necessity for medical science, that part of the work was often performed by a member of the engineer corps.

Mr. Haven.—I take pleasure now in introducing to you Major Symons, who, I think, is well known to you all. (Applause.)

Major Symons.—Mr. President and Gentlemen, the chairman of your committee has asked me to make a few remarks on the prominent features of the Government work in and about Buffalo, and I will endeavor to do so. It is rather a dry subject, but Mr. Ricker has provided something to wet it.

Very early in its history the people of Buffalo interested the general Government in their harbor, and throughout all the developments which have made this one of the great ports of the world, the general Government has been in active partnership with the people of Buffalo.

The first appropriation made by the general Government for the benefit of Buffalo harbor was one of $15,000, away back in 1826. Since then the amount expended by the Government for the benefit of Buffalo harbor has been about $5,000,000. It is not very difficult to imagine what a struggling little village Buffalo was at the time of the first appropriation; a few houses

down near the mouth of the creek, and a few hundred people gathered there, and woods and prairies all about. But the Erie Canal had just been completed and the hopes of the people were high, and there was no limit to their ambition. They had already, with money borrowed from the State, been endeavoring to improve the entrance to the harbor by dredging and building piers. The harbor inside the creek could be reached only with difficulty by the small sailing vessels of the period, and when in the creek these vessels were subject to damage from the lake rising under the influence of the Western winds and piling across the narrow neck of land separating the creek from the lake, and threatening to wash this neck away.

The earliest and most important features of the improvement work undertaken by the general Government were the construction of the piers at the entrance to the creek. It can readily be understood that without these piers the entrance must have been uncertain and dangerous, and especially so to the sailing craft of those early days. For many years a long struggle went on to build and maintain the south pier at the entrance channel. This pier, before the breakwater was built, was fully exposed to the terrific storms of Lake Erie, and it was repeatedly breached and in some instances carried away. When this happened, a little more money would be appropriated, and the pier would be patched up again and again. The history of this pier is almost pathetic as indicating the struggle made by the engineers, with little money and under many adverse circumstances, to maintain it against the fearful power of Lake Erie. To all of those who have been down to it and examined it the great strength which it was found necessary to give it is an indication of its importance and of this struggle.

The building and maintenance of the north pier was a much simpler problem, as it was protected against the worst storms by the south pier. There is no danger of this north pier getting away now, as it is being held down very securely by the Delaware and Lackawanna Railroad.

One of the earliest works undertaken by the general Government was to build a seawall to protect the neck of land lying between the lake and the inner creek, the harbor of Buffalo. This seawall is still in existence, although it is not now needed, having been supplanted by the outer breakwater, which takes its place as a barrier against the sea. Besides the good it did at the time, the construction of this seawall was a means of the city acquiring a heritage of very great value; this is the strip of land about 7000 feet long and 135 feet wide on which the seawall was built. By legislative action the city has been possessed of this strip of land for highway purposes, and I hope that it will soon take action to clear this off and convert it into a grand commercial highway running along the harbor front. I also hope that some means will be found to extend this grand future highway along the harbor front all the way to Stony Point. The existing Hamburg Turnpike would furnish the nucleus for such an extension, and I am going to ask you all as brother engineers to do everything in your power to bring this about, so that we can have a broad highway suitable for all purposes extending along the entire front of the new and great harbor of Buffalo.

The Mayor has brought this matter before the City Council and is trying with all his might to get this highway laid out and properly utilized, and the city of Buffalo is greatly indebted to Mayor Diehl for his stand on this question. But something besides the seawall and the entrance piers became necessary in the development of Buffalo harbor, and a breakwater was de-

signed to cover the entrance between the piers. Buffalo wanted this breakwater, and it got it. At first it was designed to be 2000 feet long; it was afterwards extended and extended until it finally reached a length of 7600 feet, about one and one-half miles. This was its length when I came to Buffalo about four years ago. When I came here in 1895 to take charge of the Government improvement works, there were two parties in the field, one which desired that the breakwater should not be extended farther, but with a return breakwater should be built connecting its southern end with the shore, thus making an outer harbor extending from the present harbor entrance about one and one-half miles to the south. The other party was in favor of extending the breakwater entirely through to Stony Point, about two and one-half miles farther. The latter party won, and the Government adopted the project and the work was started and is now well under way of building the breakwater from the southern end of the old breakwater entirely through to Stony Point. This work has been under way for about three years and will cost when completed about $2,000,000, and will in itself be the longest breakwater in the world, and if we consider it in connection with the old breakwater, the two together will make a breakwater defense against the seas at least 50 per cent. longer than any similar structure in the world.

About half of this breakwater at its southern end is to be timber crib structure, which does not differ in any marked degree from similar timber structures built here and elsewhere on the lakes. It does differ, however, in some of its constructive details, and it differs also from any other breakwater that has been built in the care and expense necessary to give it a good foundation. In this portion of the work the water in which it is situated is about 30 feet deep; the mud overlying the rock is from 30 to 40 feet deep, and through this mud there has been excavated an enormous trench reaching down to the underlying rock. This trench has a width of 60 feet on the bottom and an average depth of about 35 feet from the lake bottom to the rock. It was excavated by a dredge especially built for the purpose, and which I should have been very glad to have had you all see in operation. It has, however, finished its work and has been taken to the seacoast to do other work there. The trench thus excavated was filled with gravel dug out of the Niagara River down near the International Bridge. Upon the foundation so prepared the timber crib breakwater was built. It is expected that the part under water will endure practically forever, and that the part above water will last twenty to twenty-five years, and then will be replaced with a concrete superstructure.

About half of this new breakwater is composed entirely of imperishable materials, stone and gravel, no wood being used in it. This portion of the work is unique in a number of respects. It is the first stone breakwater of anything like its character to be built upon the Great Lakes and it is the first breakwater in the world, as far as I know, in which a hearting composing about one-half of its bulk is made of gravel. This gravel hearting saves about $600,000 in the cost of this portion of the breakwater, and renders it possible to complete the work within the amount which Congress was willing to allow. The cross-section of this stone breakwater was designed after a careful study, and its lines are practically the lines which would be developed by the action of storms upon an ordinary loose pile of stones. Taking this as a cross-section, we have added to its stability by covering it over from the top to a depth of 15 feet with huge stones carefully quarried out and care-

fully set in place. The contractors for the work were especially fortunate in getting a quarry from which they can get almost ideal stone for this purpose. This stone breakwater is unique in the way in which it is covered with a pavement of three enormous capping stones. No breakwater has even been built with natural stones of as great size and good quality and shape, and with these stones as carefully placed and bonded together as has this Buffalo breakwater, and I am confident that when it is finally completed and becomes known to engineers it will be regarded as one of the most monumental breakwater structures in the world.

In order that nothing should be left undone which the Government could do for Buffalo, the last session of Congress provided money for the building of a north breakwater to cover the shore area lying between the Bird Island pier and the Erie Basin, and this work has also been started, and we hope to finish it next year. This north breakwater is to be a timber crib substructure, and concrete and stone superstructure.

There are a good many other things which the Government has done and is constantly doing for the commerce of Buffalo, but I will not take up your time more than to mention in a very general way a few of them. There is the building and maintaining of the lighthouses marking the entrance to the harbor, and the entrance to Niagara River; there are five of these lighthouses right here; there are a number of buoys marking channels and shoals which are maintained by the Government; there is a large and constant expense for maintenance of the breakwater and pier structures, and the Government also at a considerable expense maintains a supervision over the navigable waters, looking out to see that they are not encroached upon in any wrongful manner.

There is a Governmental engineering project afoot in which the people of Buffalo, and particularly the engineers of Buffalo, must naturally take great interest. I allude to the proposed dam at the head of the Niagara River for the regulation of lake levels. The Deep Waterways Commission has been studying this problem for some time and I believe it is a work that is sure to come. The broad interests of lake commerce demand it, and we, here in Buffalo, must look at it from this broad viewpoint and at the same time see that the interests of Buffalo harbor and Niagara River are properly guarded. The proper designing of this dam, to hold back the waters at low stages of the lake and let them run off freely at high stages and at the same time provide for the navigation of the Niagara River, is a problem of the greatest interest, complexity, magnitude and importance.

The details of the plans of the Deep Waterways Commission have not yet been made public, and hence I do not feel at liberty to discuss them. When they do come they will certainly attract the attention of every engineer here.

I believe that it can safely be affirmed that there is no other country in the world which gives such liberal and efficient aid to its people in developing their commercial facilities and I hope that what little I have said may cause you all to feel as I do, that in all that relates to the interest and good of Buffalo, the Government is an active and efficient partner. (Applause.)

Mr. Haven.—As the officers of the United States Army are liable to be sent here, there and everywhere, it is hardly fair to ask them to become regular members of this Society; and I would ask some one to request me to recommend to the Executive Committee that Major Symons be made an honorary member of this Society. (Applause.)

Mr. Ricker.—Mr. President, I would move that you recommend to the Executive Committee that Major Symons be made an honorary member of this Society. Seconded by Mr. Bardol. Carried.

Mr. Ricker.—Mr. President, I would also move that you recommend to the Executive Committee that the Mayor of our city, the Hon. Conrad Diehl, be made an honorary member of our Society. Seconded by Mr. Bassett. Carried.

Mr. Rockwood, division engineer of the Erie Canal, urged the importance of measures for popularizing the Society and of increasing its library.

Mr. Ricker offered the following:

Resolved, That it is the sense of this Society that the Mayor's action of this day in recommending the appointment of a commission to investigate the matter of the seawall strip and to deal with the subject of this proposed great commercial highway along the water front be indorsed.

Seconded by Mr. Bassett and carried unanimously.

Mr. Bassett.—I would move that Major Symons' invitation to the Society to get out to view the breakwater at some time next summer be accepted now, and that the President be instructed to arrange with Major Symons for some date.

Mr. George Diehl.—I will second the motion. It is very courteous of Major Symons to invite us to inspect the breakwater. It is a very important and interesting piece of work.

Mr. Roberts.—I second the motion. Carried.

Mr. March.—The individual members of the Society have received a communication from the Director of the United States Geological Survey, giving a list of the topographical maps issued by that department, and I would move that the Secretary be directed to procure a set of the maps of New York State as issued by that department for the use of this Society, at whatever expense may be incurred in securing them.

Seconded by Mr. Roberts. Carried.

Interesting talks were given by Mr. Lewis on the street railway work in Buffalo, by Mr. Kielland on railway construction in South Africa, which was especially interesting at the present time, as Mr. Kielland was assistant engineer in the construction of the railroad that runs through Ladysmith. After short talks by various other gentlemen present the meeting at midnight adjourned.

G. C. Diehl, *Secretary.*

Engineers' Club of St. Louis.

498th Meeting, December 6, 1899.—Meeting was called to order at 8.25 p.m.; President Colby presiding. Twenty-two members and one visitor were present. The minutes of the 497th meeting were read and approved. The minutes of the 282d meeting of the Executive Committee were read. The Nominating Committee made its report with the following nominations:

For President—W. S. Chaplin.

Vice-President—E. J. Spencer.

Secretary—F. C. Bausch.

Treasurer—E. R. Fish.

Librarian—J. L. Van Ornum.

Directors—B. H. Colby, Wm. Bouton.

Board of Managers of Association of Engineering Societies—W. A. Layman, E. A. Hermann.

There being no further nominations, it was moved and seconded and the motion carried that nominations be closed.

The annual reports of the President and Secretary were read and on motions duly seconded were received and filed. The Treasurer's report was read by the Secretary, and on motion was referred to the Executive Committee.

On behalf of the Committees on Eads Monument and Smoke Prevention, Mr. Robert Moore made verbal reports.

Report of the Entertainment Committee was received and filed.

It was moved and seconded that the arrangements for the annual dinner be left to the Executive Committee. Motion carried.

Mr. Moore suggested that some action be taken toward filling out gaps in the files of the publications of the United States Engineers Department in the Club's Library.

Professor Nipher announced that he had nearly completed preparations for the measurement of wind pressures along the sides of the large University Building, which has a front of over 200 feet, and a depth of 45 feet. Simultaneous measurements will be made along the faces of the building, and the wind direction will be accurately determined at the instant of each pressure measurement. An invitation was extended to members and others who may be interested to at any time inspect the apparatus.

He also gave some explanation of the details of the apparatus, and some of the results of his experiments to calibrate the instruments.

The discussion was participated in by Messrs. Bryan, Colby, Kinealy and Moore. Adjourned. E. R. Fish, *Secretary.*

499th Meeting, December 20, 1899.—The annual dinner of the Club was held at the Mercantile Club at 7.30 p.m.; President Colby at the head of the table. Forty-one members and seven visitors were present. After the dinner was finished the officers for the new year were announced, as follows:

President—W. S. Chaplin.

Vice-President—E. J. Spencer.

Secretary—F. E. Bausch.

Treasurer—E. R. Fish.

Librarian—J. L. Van Ornum.

Directors—B. H. Colby, Wm. Bouton.

Members of Board of Managers of Association of Engineering Societies—W. A. Layman, E. A. Hermann.

Mr. Colby then surrendered the chair to the new President, who presided the rest of the evening.

Mr. Colby read an extremely interesting address on "Water Pollution," drawing a picture of the results of the emptying of Chicago's sewage into the Mississippi River, and showing the necessity for legislative action.

Mr. W. S. Chaplin made a short talk on "Engineering Ideals."

Mr. W. H. Bryan on the "Paris Exposition."

Capt. Edw. Burr on the "Engineer in Military Operations."

Mr. J. A. Ockerson on the "Father of Waters," and Mr. W. A. Layman on the "Engineering Panorama."

Following these a number of short speeches were made by several others.

E. R. Fish, *Secretary.*

Montana Society of Engineers.

A MEETING of the Society was held in the art room of the Butte Public Library, Butte, Mont., on December 9, 1899.

Meeting called to order by Vice-President Frank L. Sizer, at 8.30 P.M., Mr. R. A. McArthur acting as Secretary *pro tem.*

The application for membership of Edmund B. McCormick, of Bozeman, Mont., was read, and the Secretary instructed to send out the usual letter ballots.

Messrs. M. L. Macdonald and William Zaschke were appointed as tellers to canvass the ballots on membership, whereupon the chair declared Richard R. Vail and Albert Koberle to be duly elected members of the Society.

The report of the Nominating Committee of the officers for the ensuing year was read and on motion adopted, and the Secretary instructed to send out the usual letter ballots.

A preliminary report from the Committee on Arrangements for the thirteenth annual meeting, at Bozeman, Mont., was read and adopted.

Adjourned. A. S. HOVEY, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 1, 1899.—Held in the main hall of the Academy of Sciences, and called to order at 8.30 P.M., by Vice-President Hubert Vischer.

The minutes of the last regular meeting were read and approved.

Mr. George Johnston, mechanical engineer, of 326 Oak street, San Francisco, was elected to membership upon a count of ballots.

Mr. Harry Larkin, manufacturer, San Francisco, applied for associate membership. Proposed by G. W. Percy, E. T. Schild and Adolf Lietz.

It being in order to select a Nominating Committee for the purpose of choosing a list of officers for the ensuing year at this meeting, the following members were elected by acclamation: C. E. Grunsky, H. C. Behr, Adolf Lietz, Edward C. Jones and A. Ballantyne, who were instructed to prepare a ticket and report at the next regular meeting.

Mr. Max Junghaendel thereupon addressed the Society on the subject of "Hospital Arrangement and Construction," according to the most recent and approved practice, criticising therein a number of plans for the proposed city and county hospital, which were entered in competition by various local architects.

A short discussion followed, after which the meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Civil Engineers' Society of St. Paul.

ST. PAUL, DECEMBER 4, 1899.—A regular meeting of the Civil Engineers' Society of St. Paul was held at 8.30 P.M. Present, nine members and one visitor; President Estabrook presiding. Minutes of previous meeting read and approved. Letter of acknowledgment from Mrs. Archibald Johnson read and filed.

On motion of Mr. Powell, Mr. W. A. Truesdell was named to prepare a memorial to our late fellow-member, Archibald Johnson, deceased October 3, 1899.

Mr. A. W. Münster read a paper on the temporary bridge across the Mississippi River at Wabasha street, which paper he was requested to prepare for publication in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Capt. A. O. Powell presented a diagram and explained results obtained with silica cement, which is being used in the construction of the United States Government lock and dam No. 2 at this point. Interesting discussions on lumber and cement occupied considerable time.

C. L. ANNAN, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., NOVEMBER 15, 1899.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock P.M.; President C. Frank Allen in the chair. Sixty-one members and visitors present.

The record of the last meeting was read and approved.

The President announced the death of William S. Whitwell, an honorary member and one of the founders of the Society; and on motion of Professor Swain the President was requested to appoint a committee to prepare a memoir. The committee named consists of Messrs. Francis Blake and E. W. Bowditch.

On motion of Mr. Metcalf, the thanks of the Society were voted to the Engineering Department of the city of Providence for courtesies extended this afternoon on the occasion of the visit to that city.

Prof. A. H. Sabin then read a very interesting paper entitled "Protective Coatings for Structural Metals." The paper was illustrated by an exhibit of 235 steel and aluminum plates which had been coated with various oils, varnish, paints and some special preparations, and had been immersed, part of them in fresh water and part in salt water, for about two years. A discussion followed the reading of the paper, in which Professor Sabin very kindly answered numerous questions with regard to paints and coating for metal work.

Mr. J. P. Snow gave a description of the method used by the Boston and Maine Railroad for cleaning its bridges in place by means of the sand-blast, which had proved very satisfactory.

After passing a vote of thanks to Professor Sabin for his interesting and instructive paper, the Society adjourned.

S. E. TINKHAM, *Secretary.*

Civil Engineers' Club of Cleveland.

REGULAR MEETING, DECEMBER 12.—President J. A. Smith in the chair. Present twenty-five members and twenty visitors.

Messrs. B. L. Green and E. E. Boalt appointed tellers to canvass ballots for new members. Charles F. Dutton elected an active member and L. B. Stouffer an associate member.

Resolutions upon the death of Mr. Clarence A. Carpenter were read and followed by appropriate remarks from several of the members.

Application for active membership by Mr. H. L. Olmstead was read and referred to letter ballot.

Mr. Bernard L. Green, member of the Club, then read a paper entitled "A Few Notes Regarding Grade Crossings and Their Treatment." A lively discussion followed, taken part in by Messrs. J. A. Smith, Augustus Mordecai, N. P. Bowler, Ambrose Swasey, A. H. Porter, Wm. H. Searles and H. C. Thompson.

Moved and carried, that the Club adjourn until December 26, for further discussion, and that Mr. Augustus Mordecai read a paper on that date.

Adjourned, 10 P.M.

ARTHUR A. SKEELS, *Secretary.*

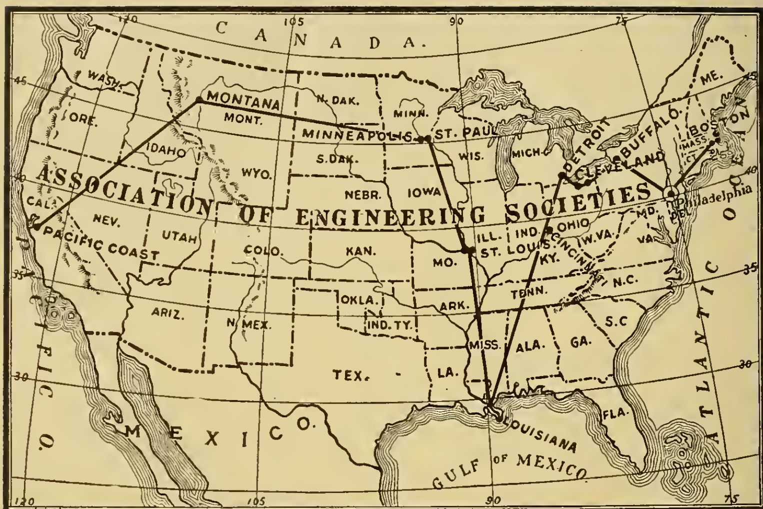
SEMI-MONTHLY MEETING, DECEMBER 26.—President J. A. Smith in the chair. Present twenty-five members, seven visitors.

No business was transacted.

Mr. Augustus Mordecai, assistant chief engineer of Erie Railroad, and member of the Club, read a paper on "Grade Crossings." Discussion followed, taken part in by Messrs. H. C. Thompson, C. H. Haupt, E. E. Boalt, B. L. Green, James Ritchie, J. A. Smith and F. C. Osborn.

Adjourned at 10 P.M.

ARTHUR A. SKEELS, *Secretary.*


ASSOCIATION OF ENGINEERING SOCIETIES
CANADA.
MONTANA
MINNEAPOLIS
ST. PAUL
DETROIT
CLEVELAND
BUFFALO
BOSTON
Philadelphia
PACIFIC COAST
ST. LOUIS
CINCINNATI
LOUISIANA
GULF OF MEXICO
MEXICO.
PACIFIC O.
ATLANTIC O.